sufficiently of late experimented, by our Mariners, that haue vsed Leuant.

Peraduenture there are some will saie, that he knoweth a good Compasse, if he see it. I saie the Compasse maie bee good, and yet not good for hym, except his Plat bee agreable. As for example. A Leuant Compasse is a good Compasse, to vse with a Leuant Plat, but it differeth from our Compasse halfe a poinct more Easterly. And others there are of Dansk, that differ from ours $\frac{1}{2}$ a poinct more Westerly, and yet beeyng vsed in their kinde, are good Compasses.

And therefore I conclude, that generally the beste Compasse is this sort set at $\frac{1}{2}$ a poincte, because the maior parte of Compasses and Plattes, doeth not differ from this aboue $\frac{1}{4}$ of a poinct, except the two aboue named of Leuant and Dansk.

I haue h[illegible] e to the Southward[illegible] ose his force, and to [illegible] not by reason of the [illegible] rather by beeyng long aient from the Stone, for not beyng touched or refreshed therewith. And again, the Pinne that beareth the Flie maie bee so dulled with long vsyng, that the Flie is as it were staied, that it can not plaie as it would if it were sharpe.

Therefore, if you make it sharpe with a Whetstone, you shall finde it remedied: and also when you finde it light, or too tickle, you maie dull the poinct of the Pinne, with the leafe of a paire of writyng Tables, vntill you maie see the top thereof, and then the Compasse will bee better for a high Sea. And thus by sharping and dulling of the Pinne, you maie make your Compasse fit for all Weathers.

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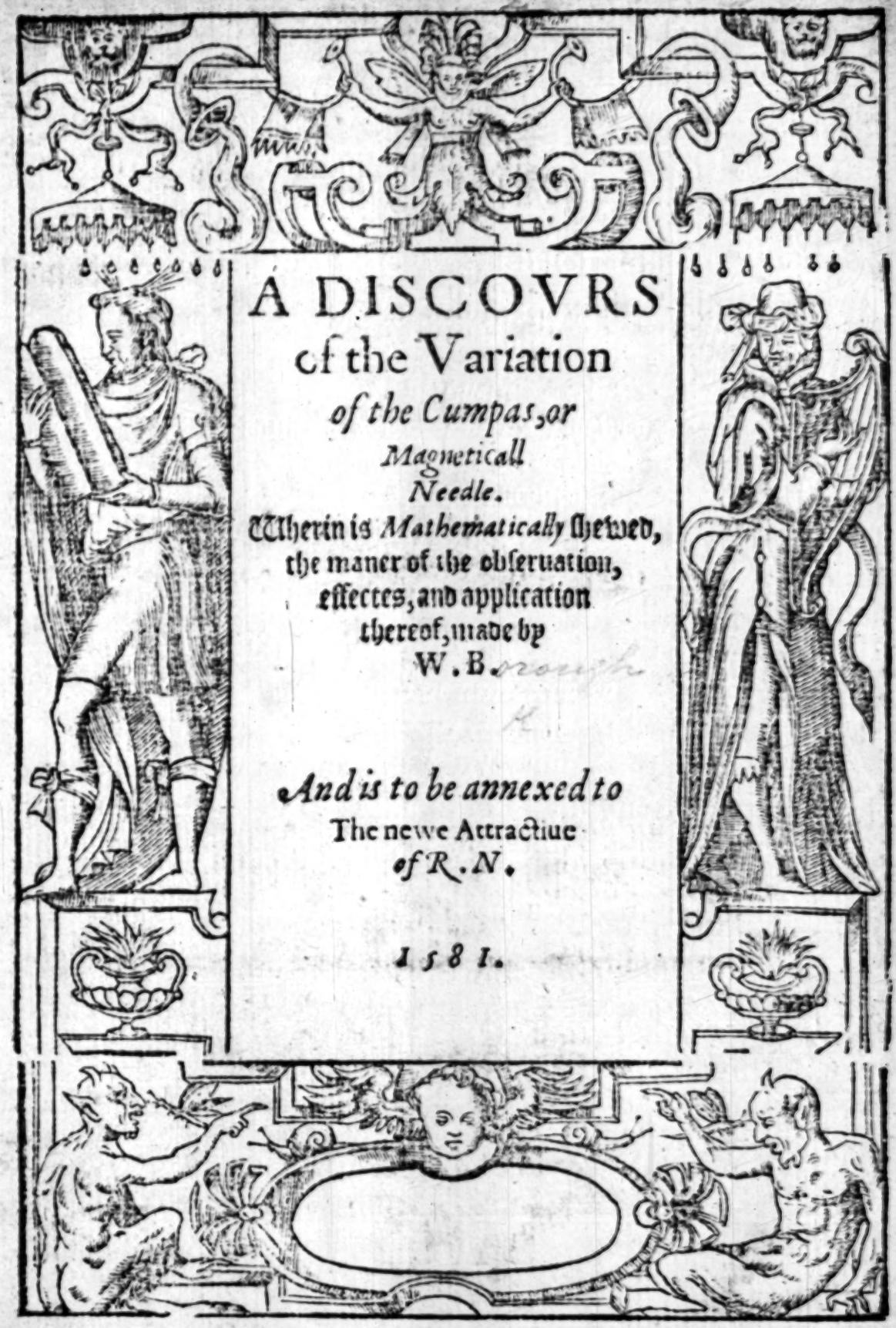


A DISCOVRS of the Variation of the Cumpas, or Magneticall Needle.

Wherin is *Mathematically* shewed, the maner of the obseruation, effectes, and application thereof, made by W. B.

And is to be annexed to The newe Attractiue *of R. N.*

1581.

To the Trauelers, Seamen, and Mariners of England.

To the Trauelers, Seamen, and *Mariners of Englande.*

HAuyng of late (gentle reader) receiued from the expert Artificer Ro. Norman, his booke intituled The newe Attractiue (who of the great good will, and affection he beareth, hath attributed in his dedication, that, whiche I acknowledge not to bee dewe) in the whiche amongest other diuers vertues and properties of the Magnes or Lodestone, he intreateth of the declinyng of the Needle touched therewith from the plaine of the Horizon, (a matter neuer before found, or written of by any). For the further behoofe and benefite of all traueilers and Seamen, I tooke occasion to inlarge the same with this discourse of the variation of the Compasse, wherein I haue handled the whole varietie of that subiect, bothe Practically, and Mathimatically, to the ende I might partly satisfie bothe the vulgar, and also the learned sort. For, knowyng the variatiō of the Cumpasse to bee the cause of many errours and imperfections in Nauigation, and perceiuyng that all those that haue as yet gone about to giue rules in that

arte, haue left this (beyng a principall poinct, and eue the grounde of all the reste) vntouched, or at least so sleightly handled the same, that little or no benefit could be gathred therby: I haue here set doune the sudrie waies to obserue the same at all tymes & places, that the inconuenience beyng knowne, might be considered of, and auoided. Wherein, although my cheefest intent hath been to pleasure those that shall haue occasion to put the thyng in practice by their owne trauaile and experience, yet because some of the rules are deducted from the fountaines of the Mathematicall Sciences, and wrought by the doctrine of Sines and Triangles, whiche maie seeme strange in our Englishe tonge, & wherwith fewe Seamen are yet acquainted, I maie seem to haue missed of my first good meanyng, but I would wishe them to chuse that whiche is plain, and conformable to their capacities, and make their profite thereof, and for the reste vnderstande, that of suche obseruations as thei them selues can not presently applie to the purpose, by others that are throughly instructed in these Mathematicall supputations, or by them selues when thei shall attaine to the knowledge therof, maie be inferred suche effectuall matter as is by these rules and preceptes promised. Wherefore I would haue all Seamen to vse suche diligence in

their

their trauailes, that no oportunitie be omitted, when, or where any obſeruation maie be made, either for the variation, or latitude of places, or of any other neceſſarie poincte incident to Nauigation, and thereof to keepe continuall notes & memoriall. For theſe obſeruations, there needeth not many troubleſome Inſtrumentes, onely for the variation, the newe Inſtrument in the ende of this treatiſe I preferre before all other. And for eleuations, a plaine Aſtrolabe exactly made, and a croſſe ſtaffe, are ſufficient. (The Globe were alſo a verie good and neceſſarie Inſtrument for beſides many pleaſaunt concluſions that maie be tried by it, it doeth lighten verie muche the conceiptes, for vnderſtandyng diuers important poinctes, but it is too troubleſome [or otherwiſe not fit for euery Mariner] to be caried to the Sea). Vnto the whiche maie bee added the Topographicall Inſtrument, for taking of diſtances, and making deſcriptions vpon the land. With theſe Inſtrumentes, and the ſailyng Cumpaſſe and Marine plat, (whiche are alwaies to be vnderſtoode the principall, and moſte neceſſarie Inſtrumentes for Nauigation, for by them onely any voiage maie bee made, but without them no Nauigation can bee performed.) the whole worlde maie bee traueled, diſcouered, & deſcribed. Theſe are ſufficient for a per-

fecte Mariner, and more then these were superfluous, onely the runnyng glasses, leades, lines, and suche like appendances of the other excepted.

But to haue all these Instruments, and not to vnderstande the groundes how to vse them, were a great vanitie. Therefore I wishe all Seamen & Trauellers, that desire to bee cunnyng in their professiõ, firste to seeke knowledge in Arithmetik & Geometrie, whiche are the groundes of all Science and certaine artes, of the whiche there is written in our Englishe tõgue, sufficient for an industrious and willyng minde to attain to greate perfection, whereby he maie not onely iudge of Instrumentes, Rules, and preceptes giuen by other, but also bee able to correcte them, and to deuise newe of hym self And this not onely in Nauigation, but in all Mechanicall Sciences. As by the studious practise and exercise in these artes, haue attained to rare and singuler knowledge: In Architecture, Vitruuius the Romaine: In paintyng that famous Germaine Albertus Durerus: And in buildyng of Shippes, Matheewe Baker our countrieman: And others in other faculties as thei haue been moste skilfull herein, so haue thei excelled. Hauyng these helpes and groundes with the Instrumentes before specified, a Mariner maie bee able to make description in platt of the coastes

Ies and Countries, and of the Banckes, Rockes, and Sholdes in the Sea, with the deapthes and other neceſſarie notes obſerued in his owne trauailes particularly, & effectually accordyng to the truthe, (which is the cheefest parte required in a perfect Mariner.) And not be alwaies tied to the reportes of other, or to the Portugale, or Spaniſhe Marine platts, which are made by the Cardmakers of thoſe Countries, men that are no trauelers them ſelues, but doe all thinges therein, by information, and vppon the credite of others, which onely committ to memorie the forme and maner of the Sea coaſtes, with making ſome fewe notes of the liyng of one place from an other, which can neuer bee ſo perfecte as the deſcriptions that are made vppon the preſent ſight and vewe of places, albeeit he be neuer ſo ſkilfull and cunnyng, that ſhall ſo cary the ſame by memorie, how muche leſſe then by the vnſkilfull. By this meanes the Cardmakers ſet doune thei knowe not what: as maie appeare by the deſcriptions of their owne coaſtes, which are verie groſſely and vnperfectly dooen, whereas the Marine plattes ought to bee deſcribed by ſuche as can giue reaſon, and ſhewe obſeruation of euery particularitie contained in the ſame, aſwell for the latitude of places, as the liyng by the Compaſſe of the Capes, Headlandes, Poin-

ctes

ctes, Flandes, Baies, Rockes, Sholdes &c. one from an other, and the distances betweene them. The errors of those descriptions, I maie not attribute to the Card-makers, but to the vnskilfull Seamen of those countries, for if thei were otherwise, as thei haue been accompted the moste skilfull of the worlde, those errors could not haue cõtinued as thei doe: true it is that for their great trauailes, thei haue been worthely famous aboue all other nations, till now at length our Countrieman Sir Frãcis Drake for valorous attempt, prudent proceadyng, & fortunate performyng his voiage about the worlde, is not onely become equall to any of them, but in fame farre surmounteth them all. But those Cardmakers, and all other that collecte and gather Hydrographical, and Geographicall descriptions of other mennes trauailes or reportes: as their paines maie bee greate, and deserue due commendation, so their doynges maie bryng commoditie diuersely. And in this behalf Abrahamus Ortelius in his Theatrum, hath deserued immortall praise, for collectyng to gether, and reducing into one cõmodious volume, the diuers plattes and descriptiõs, made by diuers and sundrie men. But amongst all those that haue made Geographicall descriptions, I can not a little maruaile at Guilielmus Postellus, who beeyng a famous learned

ned man, a greate traueiler and Cosmographer, and Deane of the Kynges Professors in the Vniuersitie of Paris, in his Vniuersall Mappe. Anno 1580. besides that it is generally handeled after suche a grosse and confused maner, that it might seeme rather to haue come from some rude vnskilfull, then from hym so famous a Doctor; hath also in the imagined Countries aboute the North Pole, so corrupted it with his fonde dreames, and fantasticall inscriptions, attributyng to those supposed landes, diuers people, as the Georgians and Hyperborians, and assignyng there to be the highest hilles of the worlde, and the people dwellyng on thē, to haue the continuall light of the Sunne; Sueta Zemlia founde by the Englishemen, An. 1550. the holie Lande, the place of the cheefest felicitie, the Hyperborean feeldes, and therefore the felicitie of the Moluccas, with many other ridiculous absurdities: That by the grosse errors of this learned man in these matters, I am taught, that what so euer fame goeth, or opinion is conceiued of any man for profound learnyng, and smothe deliueryng of their conceiptes, or what so euer greate promises are by them selues made in these artes, to iudge of them accordyng to the woorkes that come from them, and not otherwise to bee deceiued.

The Preface.

For auoidyng prolixitie in this my Preface to so small a volume, I referre the gẽtle reader, to the worke it self. Yet by the waie it shall not bee a misse, that I commende vnto you, the table of the Sunnes declination (or Regiment) made by R.N. which is calculated for the present tyme, and differeth not from the truth in any place aboue one minute, whereas in all other hetherto made and extant, there are great errors. Therfore, suche as otherwise can not from tyme to tyme calculate their declinations, accordyng to the place of the Sunne to bee giuen by the Ephemerides, and table of declination of Reinholdus maie boldly vse this Regiment for 20. yeres without any sensible errour. And so wishyng my trauailes in this treatise maie doe suche good as I ment, I commit the same to your gentle constructions, and your selues to the Almightie. At Limehouse the 26. of September. Anno 1581.

William Borough.

A Table of the Chapters contayned in the treatis.

dian, and variation of the Needle, at any place by the Sunne, vpon two obseruations, either in fornoone or afternoone.

¶ The eight Chapter.

Of the Pole of the Magnes.

¶ The ninth Chapter.

Of the point Respective.

¶ The tenth Chapter.

Of the inconueniences and defects in saylyng, and in description of Countries, caused by the variation of the Cumpas.

¶ The eleuenth Chapter.

Of the Instruments and rules of Nauigation.

¶ The twelfth Chapter.

Of the application of the Variation, to the vse of Nauigation.

Of the Variation of the Cumpas or Magneticall Needle.

Chapter I.

THE Variation of the Needle or Cumpas, is properly the ark of the Horizõ contained betweẽ the true meridiã of any place and the magnetticall meridian of the same, and is denominated to bee Esterly or Westerly, accordyng to the position of the magneticall meridian to the Eastwards or Westwards of the true meridian: And may be accompted either from the North parte, or the South parte thereof, but vppon oppolit points it hath contrary denominations.

The magneticall meridian is to bee vnderstood a greate circle passyng by the Zenith and the Pole of the Magnes, deuidyng the Horizon into two equall parts crossyng the same at oppolit points: which intersections or crossynges, are shewed by the Needle or wiers of the Cumpas touched with the Magnes or the Lodestone.

The Azimuth of the Sun is a great circle, passyng by the Zenith and the true place of the Sun: crossyng the Horizon at right Angles in oppolit poincts, and diuidyng the same into two equall parts. And it is said to be giuen when the distance thereof from the true meridian is knowne.

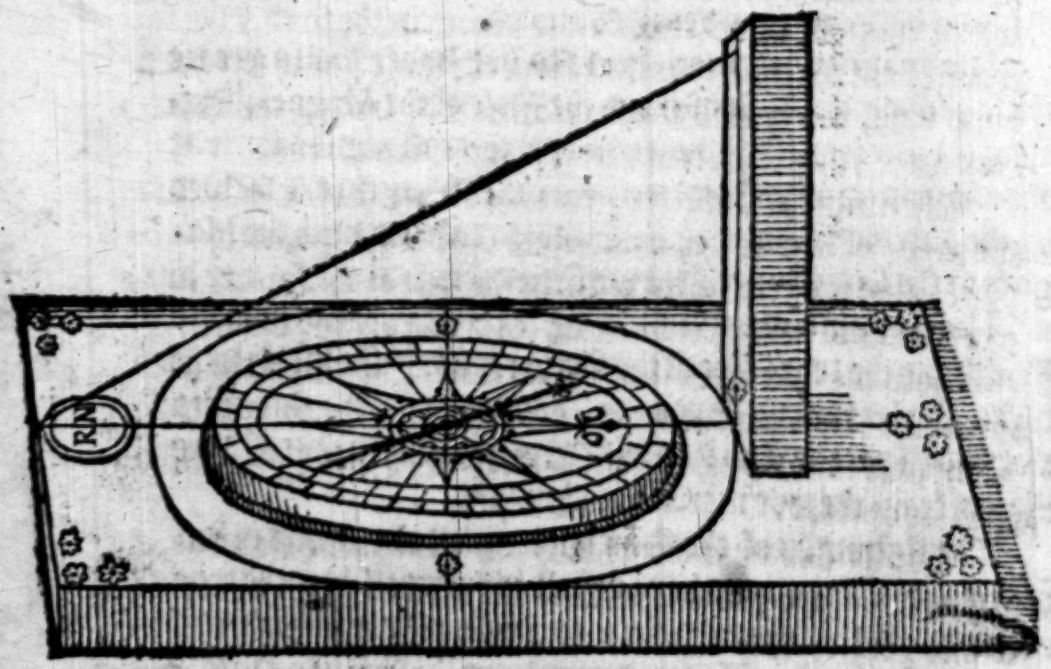
The Azimuths of the Sun vpon equall elevations in forenoone and afternoone, haue equall distances from the true meridian, so that the middle poinct of the whole difference of any two Azimuths obserued vppon equall elevations in forenoone and afternoone, is the true meridian.

This difference of Azimuths is found vppon the Instrument of Variation, by addyng together the Variations of the Sunnes shadowe at equall eleuations in forenoone and afternoone. The halfe whereof is the distance of the Azimuths from the true Meridian: the whiche compared with either of the same variations of the Sunnes shadowe, the difference shalbe the variation of the Needle from the true meridian.

Or els subtracting the lesser variation of the Sunnes shadowe, from the greater (at equall eleuations) the halfe of the remayner shall be the true variation of the Needle from the meridian.

But the Azimuth of the Sunne beyng otherwise giuen, and the variation of the shadowe likewise giuen, the difference betweens them is the variation of the Needle.

The Variation of the Sunnes shadowe I call, the Horizontall distance betweene the Azimuth of the Sunne and the magneticall circle, whiche are represented in the Instrument by the shadowe of the line and the Needle.



¶ The maner how to vse the Instrument of Variation.

¶ The second Chapter.

FIrst you must place the Instrument vpon some Stoole, or other thyng that is flat, so as it may stande leuell, and the Plummet in the Standerd which is placed at the Northende of the fixed Flye, may fall perpendicularly with the line in the same Standerd.

You must haue regard that in remouing the Instrument to the Sunne as he goeth about, it may alwaies stande leuell as afore saied.

You are then to consider, that the string that recheth from the South part of the Instrumēt, to the top of the Standerd, is the chiefest string to giue the Sunnes shadow, which must be so directed by turnyng the Instruments South side to the Sunne wards, that the shadowe of the same may fall directly longst vpon the line of South and North in the fixed Flye, for it ought not to crosse or decline from the same line in any part, but if it do, you must seeke to reforme it by setting the Standerd more vpright, or remouyng it at the South end.

Then must you also see, that the string that is fastned to the hoope of Brasse that enuironeth the fixed Flye, maie be so placed, that it agree iustly with the shadow of the former line, and the line of South and North in the fixed Flye, in such sort that both the shadowes maie be as it were hidden in the saied line of the Flye: which you maie doe aptly, by turnyng the said hoope, and remouyng the same line at either side of it, as you shall see cause.

The Instrument beyng duly placed in forme afore saied, it differeth nothyng from the Cumpas of Variation, but onely in this poinct, that whereas the Flye of the Cumpas of Variation, is so turned by vertue of the Magneticall wiers, that

the Noꝛth poinct thereof doeth shew the Pole of the Magnes oꝛ line of Variation: In this Instrument, the Noꝛth poinct of the Needle doeth supply that, whiche the Noꝛth poinct of the Cumpas should doe. And the Noꝛth poinct of the Flye which is fixed in the bottome of the Instrument, doth alwaies aunswere to the shadowe that the Sunne giueth.

¶ How to finde the variation of the Needle or Cumpas at any place, the eleuation of the Pole, and situation of the meridian vnknowne.

¶ The third Chapter.

WHen you would obserue the variation in any place, you must begin in ỹ foꝛnoone, the sooner, the better, and the moꝛe effectuall maie your obseruatiõs be, do thus.

Take your Astrolabe and obserue duly the height of the Sũne, foꝛ your moꝛe ease it shall bee best foꝛ you to note the same, when it agreeth to be iust vppon a degree, without any consideration of minuts oꝛ fractions, and at the instant of the same height, turne your Instrument to the Sunne, so as the shadowe of the lines maie fall iustly vppon the line of South and Noꝛth in the fixed Flye.

Then, when the Needle doeth stande, looke directly ouer the Noꝛth poinct of the Needle, what degree and fraction, if there be any, doth aunswere vnto the same in the fixed Flye, that is to saie, how many degrees it is from the Noꝛth of the fixed Flye, which you shall note diligently, and may saie, that so many degrees &c. is the variation of the Sunnes shadowe from the Noꝛth, as the Noꝛth poinct of the Flye is from the Noꝛth poinct of the Needle, either Eastwardes oꝛ Westwardes as you shall finde the same. Thus maie you obserue diuers tymes, vpon seuerall degrees of the Sunnes eleuation. And like as you doe in the foꝛnoone, so must you also obserue

serue the Sunnes elevation in the afternoone, vpon the same degree of height, and with the same side of the Astrolabe and Index turned towards the Sunne, as it was in the forenoone, (for auoyding of error that maie bee in the Instrument) noting at euery height what you finde the variation. And when the Sunne commeth to the meridian, it shall be good that you exactly obserue his elevation vpon the same, for knowing the true Latitude of the place: all which you shall set downe in forme following.

¶ Example.

¶ *In Limehouse the sixteenth of* October. Anno, 1580.

Fornoone.			Afternoone.			
Elevation of the Sunne.	*Variation of the shadow from the North of the Needle to the Westwardes.*		*Elevation of the Sunne.*	*Variation of the shadow from the North of the Needle to the Eastwards.*		*Variation of the Needle from the Pole or Axis.*
Deg.	Degr.	Min.	Deg.	D.	M.	D. M.
17	52	35	17	30	0	11 17 1/2
18	50	8	18	27	45	11 11 1/3
19	47	30	19	24	30	11 30
20	45	0	20	22	15	11 22 1/2
21	42	15	21	19	30	11 22 1/2
22	38	0	22	15	30	11 15
23	34	40	23	12	0	11 20
24	29	35	24	7	0	11 17
25	22	20	25	Fró N. to w. 0. 8		11 14

The eleuation of the Sunne vppon the meridian 25.d.58'. *the declination* 12.d.30'. *whiche I adde to the eleuation, because the Sunne hath South declination, and thereof amounteth* 38.d.28'. *the eleuation of the Equinoctiall, the whiche I subtract from* 90.d. *the rest is* 51.d.32'. *the eleuation of the Pole Artik.*

Now are you to consider, that out of the greater variation of shadow vpon any degree of the Sunnes eleuation, is to be taken the lesser of the same degrees eleuation, whether it bee in the forenoone or afternoone, (except the same variations be bothe one waie from the North of the Needle, whiche then are to be added) the halfe of the remayner is the variation of the Needle or Cumpas from the Pole or true meridian.

In the former obseruations, I do finde the greatest variation in the forenoone, for, at 17.d. eleuation, the variation is 52.d.35'. from North to West: And at the same eleuation in the afternoone, I finde the variation to be but 30.d.0'. frō North to East. I take the lesser out of the greater and finde remayning 22.d.35'. the halfe thereof is 11.d.17'.½. So much I say is the Pole Artik, and true meridian line that passeth to the Pole by our Zenith at London, to the Westwardes of the North that the Needle sheweth. And therefore the Needle or Cumpas varieth from the true Northe 11.d.17'.½. to the Eastwardes.

Also at 25.d. eleuation in the forenoone the variation is 22.d.20'. from North to West: at the same eleuation in the afternoone the variation is 0.d.8'. from North to West. Now because the variations are both one way, (that is to the Westwardes) I adde them together (and so ought you to doe as often as you finde the variations so to agree) and I finde that they amount to 22.d.28'. the halfe thereof is 11.d.14'. which is the variation.

The variations of the Needle or Cumpas by the former obseruations, are set out towardes the right hand against euery degrees eleuation, and conferryng them all together, I do finde the true variation of the Needle or Cumpas at Lyme-

house

house to be about 11.d.¼. or 11.d.⅓. whiche is a poinct of the Cumpas iust or little more. So that in a Cumpas whose wiers are set directly vnder the flowre de Luce, the North and by West, and South and by East poincts doe shewe the true meridian.

¶ *The eleuation of the Pole and place of the Sunne giuen how vppon the Globe, to finde the variation of the Needle by any one obseruation, either in fornoone or afternoone.*

¶ *The fourth Chapter.*

IN the former declaration, the onely way to try the variation, is by comparyng of the seuerall correspondent obseruations of the Sunnes eleuation in the fornoone, with those of the afternoone, so that if the Sunne should bee obscured, or by any other occasion like obseruation can not be made in the afternoone, then the former rule giueth not the desired purpose. Therefore I thought good to shewe, how by any one obseruation in the fore or afternoone, the eleuation of the Pole and place of the Sunne giuen, you maie knowe the true meridian and the variation of the Needle from the same in any place, whiche thing maie be done and aptly demonstrated vpon the Globe, but moste exactly calculated by the Table of Sines.

To finde out the variation vpon the Globe, you must first set your Globe to stande dewly accordyng to the eleuation of the Pole at the place proposed. Then seeke in the Ephemerides for the true place of the Sunne that daie, and note it with some small pyck in the ecliptik of the Globe. And placyng the Quadrant of Altitude or moueable verticall, at the verticall poinct or Zenith, take the eleuation of the Sunne obserued by the Astrolabe or other Instrument at the tyme proposed, and

note

note it iustly vppon the same quadrant of altitude. Then turne your Globe and quadrant towardes that part of the Horizon that the Sunne was in at the tyme of the obseruation, till the pricke you made for the place of the Sunne in the ecliptik, concur and agree iustly with the eleuation marked in the said quadrant of altitude. So shall you see the quadrant shewe you vpon the Horizon, the Azimuth and distance of the Sunne from the true meridian of that place, whiche you shall compare with the variation obserued vppon the Instrument at that instant of the Sunnes eleuation, And if they agree and concur iust, then shall you bee in the true and common meridian, whiche sheweth the Pole of the worlde and Pole of the Maynes or Lodestone: But if they differ, you shal subtract the lesser from the greater, the remayner sheweth the variation. And if the variation vpon the Instrument be greater then the true distance of the Azimuth from the meridian founde vppon the Globe, the same surplus is to be accompted for variation, vpon the contrary side of the meridian: if it bee lesse, it is to bee accompted on the same side of the meridian that the variation is taken, whether it bee in the forenoone or afternoone. This precept needeth no further demonstration, then the Instrument it self, the Globe I meane.

But for example of the worke, I take the first obseruation, in the former Chapter specified, made at Lynehouse the sixteenth of October 1580. in the forenoone, which is 17.d. eleuation, and variation 52.d.35′. from North to West.

First I set my Globe at 51.d.32′. for the eleuation of the Pole. Secondly I take the place of the Sunne 2.d.55′.m. and note it vpon the Ecliptick. Thirdly I note vpō the quadrant of altitude, the eleuation of the Sunne 17.d. This done, I moue the quadrant of altitude towardes the East of the Horizon, and turne the Globe till the prick in the Ecliptick for the place of the Sunne, doe agree iustly, with the eleuation noted vppon the quadrant of altitude, and finde the true Azimuth shewed by the said quadrant vpon the Horizon to be nexest, about 41.½. from the meridian. And conferring the same

with

with the variation founde vppon the Instrument 52.d.35'. I find the difference 11.d.15'. And because the obseruation is noted to be in the forenoone frō the North to the West, or South to the East, and the variation vppon the Instrument greater then the Azimuth founde on the Globe, I accompt the same from the North to the East, or from the South to the West. So I conclude the variation at Lymehouse to be about 11, $\frac{1}{4}$. from North to East, or South to West.

¶ How to finde the variation by Arithmeticall calculation vpon any one obseruation in the fornoone or afternoone, the Latitude of the place, and declination of the Sunne beyng giuen.

¶ The fift Chapter.

THE summe of the worke, is to finde the ark of the Horizon, betweene the meridian and the Azimuth of the Sunne at the time of the obseruation, whiche beyng compared with the variation founde in the Instrument, the difference is the variation of the Needle. For attaynyng of the same arke. First it is necessarie to haue the arke of the Equinoctiall betweene the Sunne at the tyme of the obseruation, and the meridian, which ark is thus found.

Multiply the sine of the Sunnes meridian altitude for the daie proposed, by the whole sine, the product diuide by the sine of the eleuation of the Equinoctiall (or the complement of the Latitude) the quotient is the verſed sine or shaft of the semidiurnall arke, whiche you shall note for the first nomber.

Then againe multiplie the sine of the Sunnes eleuation at the tyme of the obseruation, by the whole sine, and the product diuide by the sine of the eleuation of the Equinoctiall, the quotient subtract from the nomber you first noted, the rest is the verſed sine of the arke of the distance betweene the Sunne and the meridian in the parallell that it is in for the tyme proposed,

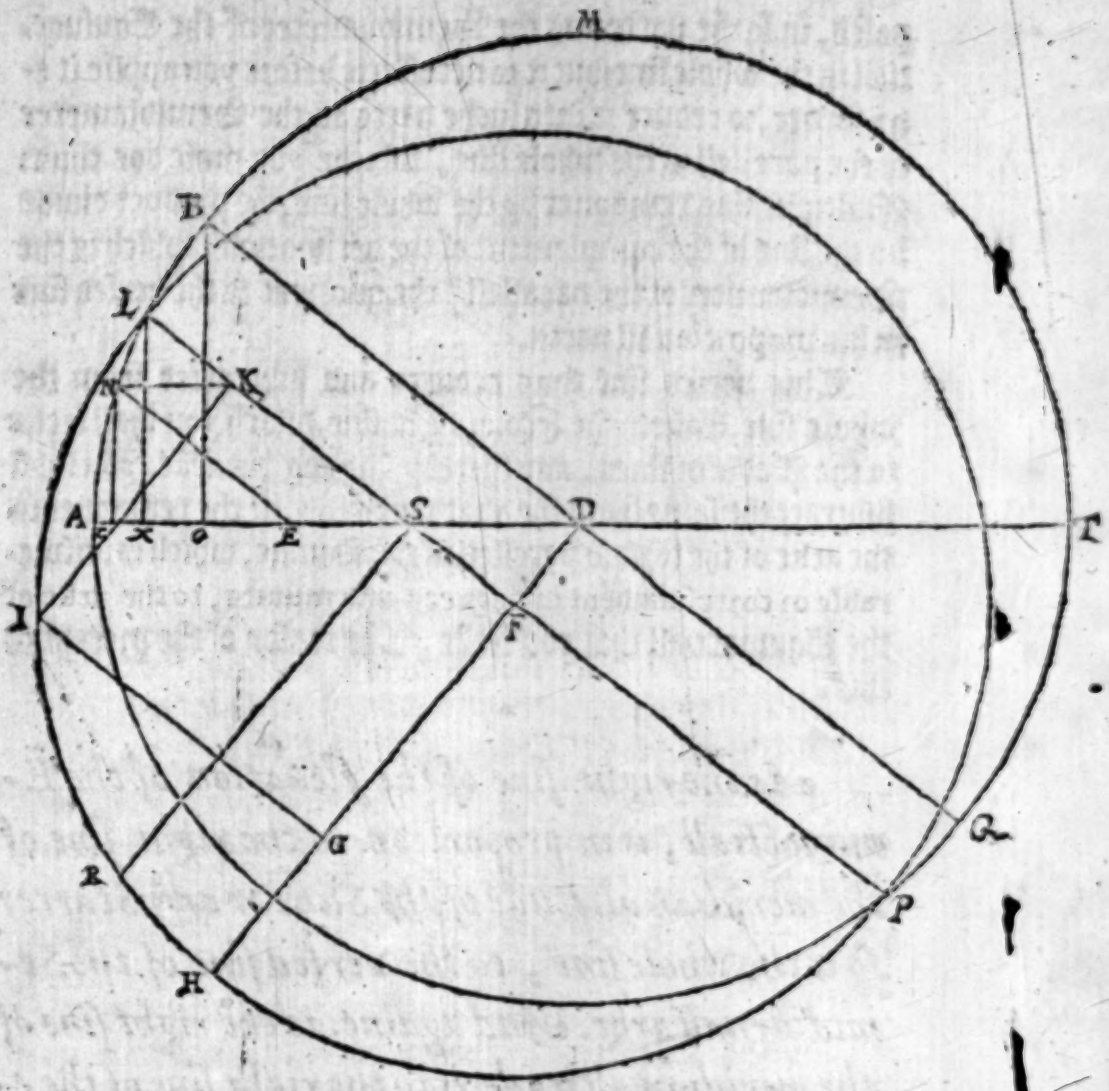
poſed, in ſuche partes as the Semidiameter of the Equinoctiall is the whole ſine: but it is neceſſarie before you applie it any furder, to reduce it into ſuche parts as the Semidiameter of the parellell is the whole ſine, whiche you maie doe thus: Multiplie this remayner by the whole ſine, the product diuide by the ſine of the complement of the declination (which is the Semidiamiter of the parallell) the quotient is the verſed ſine in his proportionall parts.

This verſed ſine thus reduced and ſubtracted from the whole ſine, leaueth the ſecond right ſine, which you ſhall ſeeke in the Table of ſines, and thereby finding his arke, you ſhall ſubtract the ſame from the quadrant or 90.d. the remayner is the arke of the foreſaid parellell of the Sunne, which is anſwerable or correſpondent in degrees and minuts, to the arke of the Equinoctiall that you ſeeke. The reaſon of the precept is this.

As the right ſine of the eleuation of the Equinoctiall, is in proportion to the right ſine of the meridian altitude of the Sũne or any Starre: ſo is the whole ſine, to the verſed ſine of the Semidiurnall arke. And againe, as the right ſine of the meridian altitude, is to the right ſine of the eleuation of the Sunne or Starre at the tyme of the obſeruation: So is the verſed ſine of the Semidiurnall arke of the ſame, to the exceſſe or difference betweene the ſame verſed ſine and the verſed ſine of the diſtance from the meridian.

For the better vnderſtanding of the premiſſes, I haue ſet downe this figure following, and wiſhe the Reader to conſider of the ſame with the 4. Pro. of the 6. of Euclide.

Let



LEt A M T. be the meridian circle. B D Q. the common ſection of the meridian and Equinoctiall their playnes, whiche is alſo the diameter of both circles. A D T. the plaine of the Horizon. L H P. the parallell of the Sunne, whiche is deſcribed vpon the centre F. at the diſtance F L. whiche is the ſine of the complement of the declination. A B. the arke of the eleuation of the Equinoctiall. B O. the firſt right ſine thereof. A L. the arke of the meridian altitude. L X. the ſine thereof. A N. the arke of the Sunnes

eleuation at the tyme of the obſeruation. N C. the ſine thereof. B D. the whole ſine in reſpect of the former arkes and ſines. L R. the Semidiurnall ark of the parallell. R S. the firſt right ſine thereof. S L. the verſed ſine of the ſame. L I. the ark of the Sunnes diſtance from the meridian. I K. the firſt right ſine thereof. I G. the ſecond right ſine, which is equall to K F. K L. the verſed ſine. N E. which is equall to K S. the differēce of the 2. verſed ſines L S. and L K. L F. the whole ſine in reſpect of the arks and ſines of the parallel.

Now as B O. is to L X. ſo is B D. to L S. And as L X. to N C. ſo is L S. to N E. Or els thus, as B O. to N C. ſo is B D. to N E.

Example.

The 16. October, 1580. in Lymehouſe.

The eleuation of the Pole Artik 51. d. 32'. The declination of the Sunne 12. d. 30'. The elenation of the Sunne obſerued in the forneone 17. d. 0'. The variation of the ſhadow vpon the Inſtrument 52. d. 35'. from North to Weſt.

38. 28'.	90. 0'.	25. 58'.	
B O.	B D.	L X.	L S.
If. 62205. giue.	100000.	—then. 43784. giueth.	70386.
38. 28'.	90. 0'.	17. 0'.	
B O.	B D.	N C.	N E.
Againe if. 62205. giue.	100000.	29237. ſhall giue.	47001.

Now out of. L S. — 70386.
take. N E. — 47001.

Reſt. L K. — 23385.

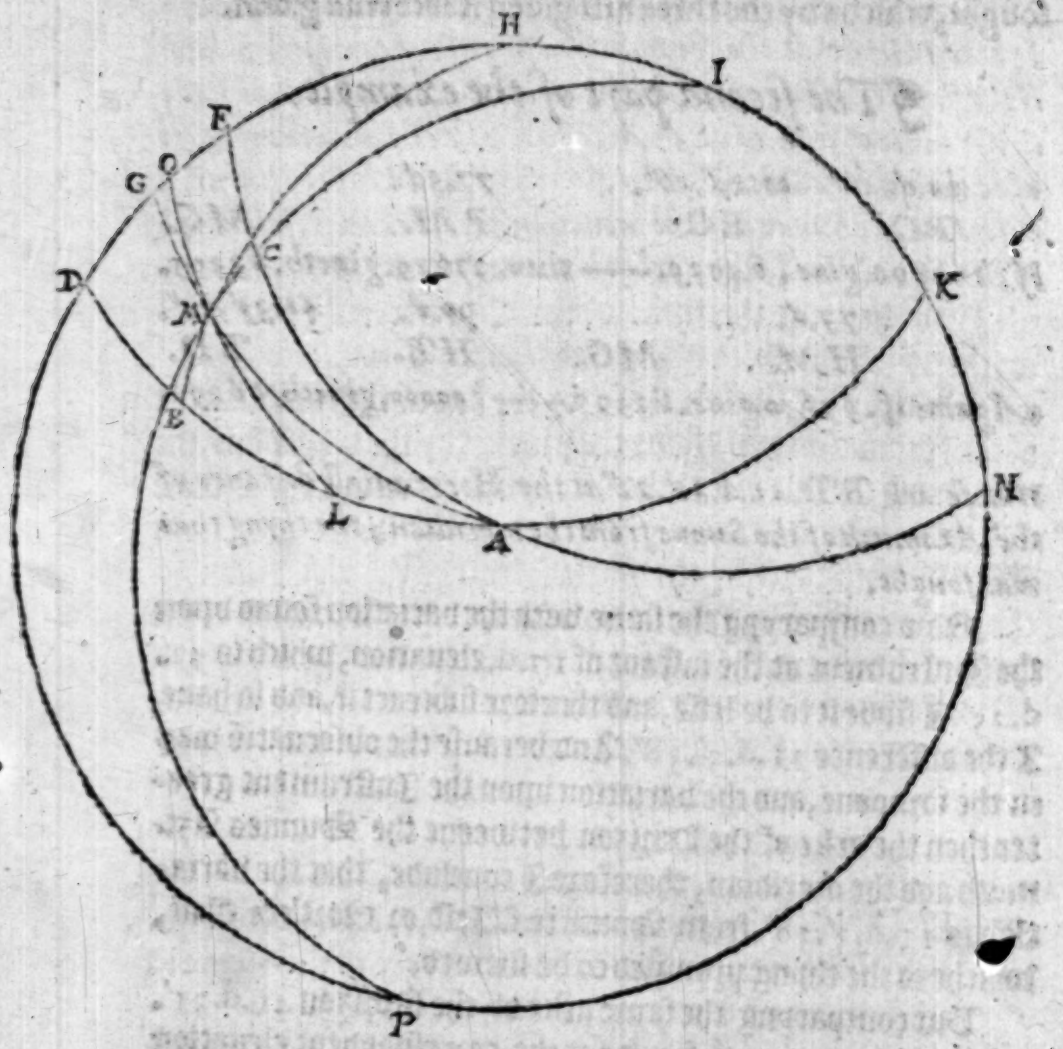
Then if L F. 97629. the ſine of 77. d. 30'. the complement of the declination, giue L F. 100000. then L K. 23385. giueth L K. 23952. the verſed ſine of the arke I L. in his dew partes.

The

The same subtracted from L F. 100000. the whole sine, leueth K F. or I G. 76048. the second right sine of the same ark, which is the first right sine of the arke I H. whiche arke you shall finde in the table of sines to be 49. d. 30'. 24''. the complement whereof to the quadrant is 40. d. 29'. 36''. the arke I L. of the parallell betweene the Sunne and the meridian, whose correspondent ark in the Equinoctiall, is the arke that was sought.

Now hauyng [illegible] Equinoctiall, you must worke [illegible] sine thereof, by the sine of the complement of the declination, and diuide the product by the whole sine, the quotient is the sine of an arke contayned betweene the Sunne and the meridian, makyng right angles with the meridian. This sine multiply by the whole sine, the product diuide by the the sine of the complement of the Sunnes eleuation at the tyme of the obseruation, the quotient shalbe the sine of the ark of the Horizon contained betweene the Azimuth of the Sunne and the meridian, whiche is the arke that was proposed to be found.

LEt D H N P. be the meridian. D A K. the Horizon. E A N. the Equinoctiall. M. the place of the Sunne in the heauen at the tyme of the obseruation. L M O. the parallell. H M B. the Azimuth or verticall circle passing by the Sunne. A M G. a greate circle imagined to passe by the Sunne, & to crosse the meridian at right angles. I M P. a greate circle passyng by the Poles of the worlde, and place of the Sunne at the tyme of the obseruation, commonly called the citcle of houres, or circle of declination. C M. the South declination of the Sunne [illegible]. the complement thereof to the quadrant. [illegible] the ark between the Sunne and th[illegible] of the former imagined circle. A M G [illegible] ark of the Sunnes parallell, E C. the correspondent [illegible] of the Equinoctiall, which are giuen in the former work. M B. the eleuation of the Sunne at the tyme of the obseruation.



tion. M H. the complement thereof. B D. the ark of the Horizon intercepted betweene the Azimuth and the meridian, which is the thing required to be found.

In this figure the Reader is to consider the maner of the spherical triangles, and to compare the sines of their sides, according to the doctrine of Copernicus. in the 14. Chapter of his first booke, and of Regiomontanus. his 25. and 27. propositions of his 4. booke of triangles.

As P C. is to C E. so is P M. to M G. but 3. of them are giuen, therefore the fourth shall be knowen.

And as H M. is to M G. so is H B. to B D, the arke that is

sought,

ſought, whiche by the three firſt giuen is likewiſe giuen.

¶ The ſecond part of the example.

90.d.	40.29'.36''.	77.30'.	
PC.	EC.	PM.	MG.
If. 100000. giue.	64935. ——	then. 97629. gineth.	63395.
73.d.		90.d.	41.31'.22''.
HM.	MG.	HB.	BD.
Againe if. 9[illegible].	giue. 63395. ——	100000. gineth.	66291.

Whoſe [illegible]*BD.41.d.31'.22''. is the Horizontall diſtance of the* [illegible]*muth of the Sunne from the meridian, the thyng that* [illegible]*ught.*

Now comparyng the ſame with the variation found vpon the Inſtrument at the inſtant of 17.d. eleuation, which is 52. d.35'. I finde it to be leſſe, and therfore ſubtract it, and ſo haue I the difference 11.d.3'.38''. And becauſe the obſeruatiō was in the forenoone, and the variation vpon the Inſtrument greater then the arke of the Horizon betweene the Sunnes Azimuth and the meridian, therefore I conclude, that the variation is 11.d.3'.38'', from South to Weſt, or North to Eaſt, whiche is the thyng promiſed to be ſhewed.

But comparyng the ſame arke of the Horizon 41.d.31'. 22''. with the variation founde at the correſpondent eleuation in the afternoone, which is 30.d.o'. I ſubtract the leſſer from the greater, and finde the exceſſe 11.d.31'.22''. whiche ſhould be the variation. And becauſe the variation founde vppon the Inſtrument is leſſe then the arke of the Azimuth vppon the Horizon, I accompt the variation on the ſame ſide of the meridian, whiche is from South to Weſt, or North to Eaſt.

This varietie betweene the obſeruation made in the forenoone, and that in the afternoone, proceedeth either of the imperfection of the Inſtrument, or negligence of the obſeruer. For in the rule there can bee no error, beyng grounded vppon Geometricall demonſtration, then whiche nothyng can bee

more

more certaine.

The former preceptes and examples doe serue when the Sunne doth decline frō the Equinoctiall either Northwards or Southwardes. But if the Sunne be in the Equinoctiall, then the maner of the worckyng is more easie and brief. For if you multiplie the sine of the Sunnes eleuation at the tyme of obseruation, by the whole sine, and diuide the product by the sine of the eleuation of the Equinoctiall, whiche is the meridian altitude, the quotient giueth the seconde right sine of the distance of the Sunne frō the meridian, whiche is the first right sine of the complement of the same arke: And entryng the table of sines with it, you shall finde his arke, whiche if you subtract frō the quadrant or 90.d. leaueth the arke of the distance of the Sunne from the meridian. And hauyng the same worck thus. If the sine of the complement of the eluation of the Sun at the tyme of the obseruation, giue the sine of the forsaid arke of distance, what shall the whole sine giue. Multiplie and diuide, the quotient shalbe the sine of the ark of the Horizon contayned betweene the Azimuth of the Sunne and the meridian. Which arke being compared with the variation of the Instrument in maner as before is shewed, giueth the variation required.

But the Sunne beyng in the Equinoctiall, if the place where the obseruation is made, bee likewise vnder the same circle; then is the variation most easely obserued, for that the Equinoctiall is the Azimuth of East and West, therfore turnyng your Instrument onely to receiue the shadowe of the Sunne, and looking then to the North poinct of the Needle, if you finde the same to aunswere to the quadrant or 90.d. you shall be in the meridian of the Magnes, whiche passeth by the Poles of the world, but if it doe differ from 90.d. the same difference is the variation of the Needle.

But admittyng the obseruer to be vnder the Equinoctiall, and the Sunne to haue declination, then the proportion of the sine of the complement of the eleuation at the tyme of the obseruation, vnto the sine of the declination, shalbe suche, as the

whole

whole sine, is to the sine of the arke of the Horizon included betweene the Azimuth of East and West, which is the Equinoctiall it self, and the Azimuth of the Sunne for the tyme of the obseruation, the complement whereof giueth the true meridian, whiche complement you maie compare with the variation shewed vpon the Instrument, the difference is the variation.

Diuers other cases might bee proposed, and rules giuen for them, whiche for breuitie I omit.

But one thyng I thought good to admonishe you by the waie, that whereas I haue shewed in the first part of this proposition the maner to finde the two versed sines, the one of the Semidiurnall arke, the other of the arke of the distance of the Sunne from the meridian. By the first, the Semidiurnall arke being found and reduced into houres and minuts of time, is shewed the iust quantitie of the daie. And by the arke of the other likewise reduced, the houre of the day, or the tyme contained betweene the noonsteed and the instant of the obseruation. As in the same example. The versed sine of the Semidiurnall ark LS. is giuen 70386. in suche parts as the Semidiameter of the Equinoctiall B D. is 100000. therefore I reduce the same into such parts as the Semidiameter of the parallel L F. is 100000. and finde it to be 72095. which subtracted from the whole sine L F. 100000. there resteth S F. 27905. whiche is the second right sine of the Semidiurnall ark L R. and the right sine of R H. 16. d. 12′. whiche is the complement of the Semidiurnall ark L R. wherefore subtractyng it from the quadrant L H. or 90. d. resteth 73. d. 48′. the Semidiurnall ark L R. the same reduced into partes of tyme allowyng 15. d. for an houre 15′. for a minut, and 15″. for a seconde of tyme, and for euery degree 4. minuts of tyme, for euery minut 4″. and for euery second 4‴. &c. I finde the time of that ark from the pointe ascendent, to the meridian, whiche is halfe the day, to bee 4. houres 55′. 12″. and consequently the whole day beyng the 16. of October aboue written, to be 9. houres 50′. 24″. long.

This example maie serue for a generall precedent, whiles the Equinoctiall is betweene the Sunne & the eleuated Pole, but if the Sunne be betweene the eleuated Pole and the Equinoctiall, then will the verſed ſine fall out to be greater then the whole ſine, and the Semidiurnall arke to exceede a quadrant. Wherefore hauyng reduced the ſame into his proportionall parts, as before is ſhewed, ſubtract from it the whole ſine, the ſurplus is the ſine of the exceſſe of the Semidiurnall arke aboue a quadrant, whiche beyng added to the quadrant, giueth the Semidiurnall arke.

By the other verſed ſine of the diſtance of the Sunne from the meridian, which is L K. 23952. in ſuch parts as the whole ſine or Semidiameter L F. is 100000. ſubtracted from the whole ſine, is giuen K F. 76048. the ſecond right ſine of the ſame ark of diſtance, and the firſt right ſine of 49. d. 30′. 24″. which is the complement of the ark of the Sunnes diſtance from the meridian: therefore ſubtractyng the ſame from 90. d. reſteth 40. d. 29′. 36″. the arke of the diſtance betweene the Sunne and the meridian, which beyng reduced into partes of time as before, giueth 2. houres 41′. 58″. and the ſame (becauſe it is in the forenoone) deducted from 12. houres the noonſteed, reſteth 9. houres 18′. 2″. the iuſt inſtant of the tyme of the day.

But if this verſed ſine be found to be greater thē the whole ſine (as it maie when the Sunne is betweene the Equinoctiall and the eleuated Pole, and before the houre of ſixe in the morning and after the houre of ſixe in the euening) then doth the arke of diſtance conſequently exceede a quadrant, the ſine of this exceſſe is the ſurplus of the verſed ſine aboue the whole ſine. Whoſe arke added to the quadrant giueth the arke of the Sunnes diſtance from the meridian, and reducyng the ſame into parts of tyme, is giuen the inſtant of tyme of the obſeruation.

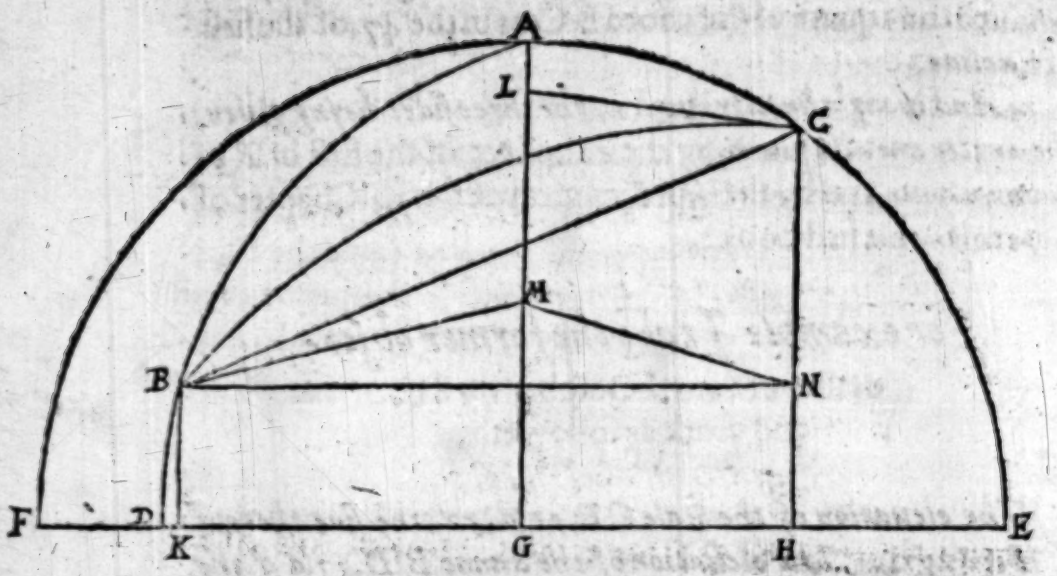
As by this meanes (the eleuation of the Sunne being preciſely obſerued and Latitude knowen), the inſtant of time of ỹ daie is giuen more exactly, then by any Clock, Diall or other Inſtrument. So if there might be had a portable Clocke that would

would contime true the space of 40. or 50. houres together (if longer tyme the better) then might the difference of longitude of any two places of knowen Latitudes, whiche conueniently may be trauelled within that time, be also most exactly giuen. And in this sort trauelling and obseruing from place to place, might the longitudes of any Countrey be perfectly described.

¶ An other way most generall, how to finde the Variation by one obseruation either in the fornoone or afternoone, the eleuation of the Pole and declination of the Sunne beyng giuen.

¶ The sixt Chapter.

FOR the accomplishyng of this proposition, you are to imagine a sphericall triangle vppon the superficies of the Globe, whose sides must be. First the portion or arke of the meridian betweene your Zenith and the Pole, whiche is the complement of the latitude. The second the ark of the verticall circle contayned betweene your Zenith and the Sunne, which is the complement of the Sunnes eleuation at the tyme of the obseruation. The third side is an arke of the circle of declination comprehended betweene the Sunne and the eleuated Pole, this arke is found by addyng, or subtractyng, the declination of the Sunne, to or from, the quadrant or 90. d. whiche must be done with this consideration, that if you be on the same side of the Equinoctiall that the Sunne is, you are to subtract the declination from the quadrant. If on the other side, to add it to the same, so haue you the three sides of the sphericall triangle giuen. Then the substance of the work consisteth in findyng the quantitie of the angle of the same triangle at the Zenith, for the complement thereof to the Semicircle or two right angles, is the Horizontall distance of the Sunnes Azimuth from the meridian, which beyng compared with the variation of the Sunnes shadowe vppon the Instrument, giueth the thyng required.



LEt F A C E. be the meridian, wherein A. the Zenith, C. the Pole. A D. the verticall circle or Azimuth of the Sunne passyng by B. the place of the Sunne at the tyme of the obſetuation. B D. the eleuatiō of the Sunne. B A. the complement of the eleuation. A C. the complement of the latitude. B C. the ark of the circle of declination, or the chord of the ſame ark. F G E. the plaine of the Horizō.

Now from the three angles of the triangle A B C. let fall 3. perpendicular lines to the plaine of the Horizō A G. C H. and B K. and by the 6. of the 11. of *Euclide*, theſe three lines ſhall be parallelles.

Then let fall a perpendicular line from C. vppon A G. in the poinct L. from B. an other perpendicular vppon the ſame line A G. at the poinct M. And from the ſame point M. erect a perpendicular line to N. which ſhalbe parallell and equall to L C. Then ioyne B. and N. together. So haue you a right-lined triangle. B M N. whoſe angle at M. is equall to the angle A. of the ſphericall triangle A B C. By the 4. definition of the 11. of *Euclide*, for the like reaſon is of obtuſe angles as of acute or ſharp. And the ſides therof B M. and M N are giuen B M. the ſine of B A. and M N. equall to L C. the ſine of C A.

And

And the third side B N. is found by subtracting the square of N C. frō the square of the chord B C, as in the 47. of the first of *Euclide*.

And in right lined triangles, the three sides beyng giuen, the angles are also giuen, by the 44. 45. &c. of the first of *Regiomontanus*, and by the 7. proposition of the 13. Chapter of *Copernicus* his first booke.

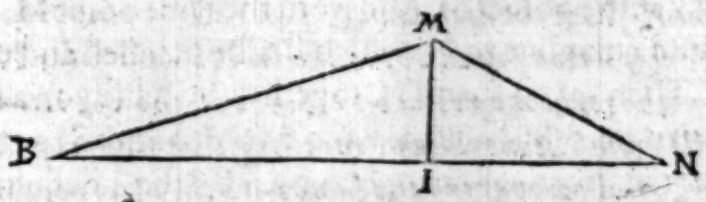
For example I take the former obser-
uation of the 16. October 1580.
and work as followeth.

The eleuation of the Pole C E. 51. d. 32'. the sine thereof C H. 78297. The eleuation of the Sunne B D. 17. d 0'. the sine thereof B K. 29237. The arke B C. 102 d. 30'. the chord thereof B C. 155976. The complement of the eleuation of the Sunne B A. 73. d. 0'. the sine thereof B M. 95630. The complement of the latitude A C. 38. d. 28'. the sine therof L C. 62205. equall to M N. Now out of C H. 78297. subtract N H. equall to B K. 29237. Rest N C. 49060.

Then out of the chord B C. squared. —— 24328512576.
Take the square of N C. —— 2406883600.

Rest the square of B N. —— 21921628976.
The roote thereof is. 148059. the side B N.

So are the three sides of the triangle giuen.
B N. 148059.
M N. 62205.
B M. 95630.



Now to finde the angle M. I subtract from the square of B M. the bigger side, whiche is. 9145096900. the square of

M N. the lesser side, which is. 386946025. Rest 527563475. which diuided by the base B N. 148059. gineth 35631. which number I take out of the said base rest. 112428. the half ther-of. 56214. is I N. the lesser case or shorter parte of the base diuided by the perpendicular line M I. fallyng vpon the same frō the obtuse angle M. whiche subtracted from the whole base B N. 148059. leaueth I B. 91845. the greater case or longer part thereof.

Now it is manifest that these two cases or parts of the base B I and I N. are the sines of the two sharpe angles I M B. and N M I. made of the obtuse angle M. by the perpendicular fallyng from the same angle to the base, and the arks of them ioyned together, are the quantitie of the obtuse angle N M B.

Therefore to reduce them to the nombers of the sines, first for the greater case B I. making B M. the whole sine, say.

B M.	*B M.*	*B I.*	*B I.*
If. 95630. giue. 100000.	*— then shall. 91845. gine. 96042.*		

The ark thereof is 73. d. 49'. 38". Againe for the lesser case, making M N. the whole sine, say.

M N.	*M N.*	*I N.*	*I N.*
If. 62205. giue. 100000.	*— then. 56214. gineth. 90376.*		

Whose ark is 64. d. 38'. 45". And addyng these two arks together they giue 138 d. 28'. 23". the ark or quantitie of the obtuse angle N M B. equall to the spherical angle B A C. And deductyng it frō the Semicircle 180. d. there resteth 41. d. 31'. 37". the angle F A D. the Horizontall distance of the Sunnes Azimuth from the meridian, & subtractyng that from 52. d. 35' the variation found vppon the Instrument from North to West in the fornoone, resteth 11. d. 3'. 23". the variation of the Needle from the meridian, the thyng that was proposed to be found. And comparyng the same with the afternoones obseruation, you shall finde it 11. d. 31'. 37". the cause of this difference I haue declared in the former Chapter.

If the Reader be deligted with varietie of demonstrati-

on of this matter, let him peruse the 34. proposition of the 4. of Regiomontanus, and the 13. proposition of the 14. Chapter of the first booke of Copernicus.

But whereas you see this calculation to differ from the former in some odde seconds, the reason thereof is not as it might bee taken the different nature of the rules, but in worcking thereof, omitting the fractions in the diuisions, and neglectyng the proportionall parts of the lines and arks.

In these exãples I haue vsed ỹ abridged table of 100000. the whole line, which though it giue some ease in the worcking, yet it is not so exact as that of 10000000. of Erasmus Reinholdus. Unto the which, with his Canon fœcundus annswerable to the same, if the third Canon of the Hypothenusaes were annexed, we should haue an entire table for the doctrine of triangles, that might worthely bee called The table of tables. Whiche thyng though Georgius Ioachimus Rheticus, haue well begun and framed it orderly frõ ten minuts to ten: yet is it left very rawly for suche as desire the exact truth of thynges. I haue therefore for myne owne ease and vse, calculated the complement of this table, and almost ended it, for the whole quadrant from minut to minut: whiche if in the meane tyme before I haue finished, I shall not finde it extant by any other, I will publiche it for the commoditie of all suche as shall haue occasion to vse the same for Nauigation and Cosmography.

¶ To finde the eleuation of the Pole, Situation of the meridian, and Variatiõ of the Needle at any place by the Sunne, vpon twoo obseruations either in forenoone or afternoone.

¶ The seuenth Chapter.

Whereas in the three last Chapters, the groundes of the calculations consist in the eleuation of the Pole to be giuen, which thyng to knowe is no lesse difficult,

cult, then the cheef matter that is by them required. For the common precepts, whiche as yet haue theefly been giuen for the findyng thereof, depende onely vppon the obseruation of the meridian altitude of the Sunne or Starres, or els vppon certaine falſe and groſſe rules of the guardes and Pole ſtarre. Therefore I haue thought good, that as I haue ſhewed the waie to know the variatiõ vpon any one obſeruation, either in forenoone or afternoone, the latitude of the place preſuppoſed: ſo likewiſe, vpon twoo obſeruations by the Sunne, either in forenoone or afternoone, to ſette doune the waie and maner how to finde the eleuation of the Pole, ſituation of the meridian, and variation of the Needle in any place by the Globe.

But this you muſt alwaies regard, that your twoo obſeruations maie haue conuenient diſtance of tyme betweene them, the greater the better: So as the higher eleuation bee not taken nere the meridian, the lower eleuation the nerer it is taken to the Azimuth of Eaſt or Weſt, or to the Horizon, the better, with which eleuations, you are to note the difference of the Sunnes Azimuths or variations founde by the ſhadowe vppon the Inſtrument exactly, for without that, the eleuations onely are in vaine.

Firſt it is requiſit, that your Globe be ſo fitted, that the meridian circle and the Horizon doe croſſe eche other at right angles, and diuide them ſelues equally into Semicircles. And alſo that the quadrant of altitude (or moueable verticall) bee placed duly vpon the meridian circle at the Zenith, ſo as being turned circularly, it may touche the Horizon equally in euery part. Theſe thinges beyng duly conſidered, there needeth not any further regard to bee had for placyng of the Globe, onely this you may reſpect in ſettyng the Pole at aduentures aboue the Horizon betweene it and the Zenith, that the meridian circle may cut the Horizon in iuſt degrees, ſo may your quadrãt of altitude be placed at your Zenith iuſtly vpon a degree alſo.

Then muſt you faſten your Globe to the Horizon, ſo as it may remaine immoueable, but in faſtnyng the ſame you muſt regard that you force it not from one ſide of the Horizon to an

other

other, but that it reſt equidiſtãt in the ſame. And hauyng your Globe thus diſpoſed, it is ready for you to apply your obſeruations vpon, which you ſhall thus doe.

Firſt, take your higheſt eleuation, and note it vpon your quadrant of altitude, and place the ende of the ſaied quadrant vpon the Horizon at 10. 15. or 20. d. frõ the meridian circle, (but the nerer you ſet the ſame to the meridian, the more conuenientlp, without impechement, will your triall bee made.) Then giue a pricke vpon the Globe in the Azimuth, that the quadrant ſheweth at the degree of the eleuation, noted vpon the quadrant, then againe note the leſſer eleuation vpon the quadrant of altitude, and remoue the ſame vpon the Horizon (from that place where it was firſt fixed, towardes the Azimuth of Eaſt or Weſt, whiche ſhalbe nereſt the ſame) ſo manp degrees as pou finde the difference of Azimuthes betwene the twoo eleuations bp the ſhadowe of the Sunne, vpon the inſtrument of Uariation, and ſtaipng your quadrant of altitude vpon that poinct of the Horizon: note alſo your leſſer eleuation in the ſame Azimuth vpon your Globe. This doen you muſt haue a paire of Calliper compaſſes, ſuche as maie conuenientlp reche to 113. d. ½. of the Equinoctiall of your Globe, (whiche is a quadrant, and the greateſt declination of the Sunne) then pou muſt conſider whiche of the Poles of the worlde is eleuated aboue your Horizon, and whether your declination bee towardes, or from that Pole, that is to ſaie, whether the Sunne be betweene the eleuated Pole and the Equinoctiall, or the Equinoctiall betweene the Sunne and the Pole. If the Sunne bee betweene the Pole and the Equinoctiall, then are you to ſubtracte the declination from 90. d. If the Equinoctiall bee betweene the Sunne and the Pole, you muſt adde the declination to 90. d. And take the ſame remainyng or collected number of degrees &c. with your compaſſes vpon the Equinoctiall. And ſett the one ende of your compaſſe at the pricke made vpon your Globe, for the higheſt obſeruation, and with the other ende deſcribe an arke or peece of a circle, vpon the ſame ſide of the meridian that your pricke

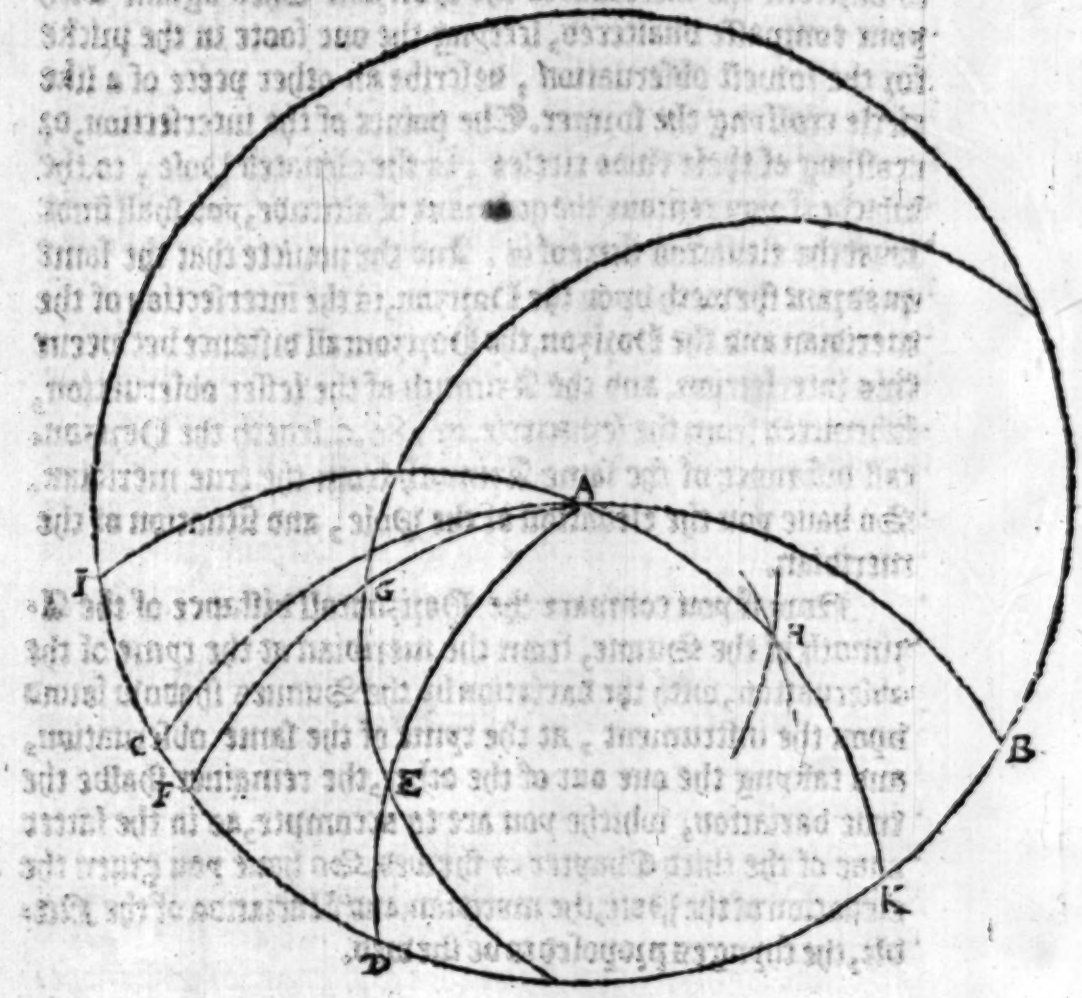
is on, from the meridian to the Horizon. Then againe with your compasse vnaltered, settyng the one foote in the pricke for the lowest obseruation, describe an other peece of a like circle crossyng the former. The poinct of the intersection, or crossyng of these twoo circles, is the eleuated Pole, to the whiche if you remoue the quadrant of altitude, you shall finde what the eleuation thereof is. And the poincte that the same quadrant sheweth vpon the Horizon, is the intersection of the meridian and the Horizon, the Horizontall distance betweene this intersection, and the Azimuth of the lesser obseruation, subtracted from the semicircle, or 180. d. leueth the Horizontall distaunce of the same Azimuth from the true meridian. So haue you the eleuation of the Pole, and situation of the meridian.

Now if you compare the Horizontall distance of the Azimuth of the Sunne, from the meridian at the tyme of the obseruation, with the variation by the Sunnes shadow found vpon the instrument, at the tyme of the same obseruation, and takyng the one out of the other, the remainer shalbe the true variation, whiche you are to accompte, as in the latter ende of the third Chapter is shewed. So haue you giuen the eleuation of the Pole, the meridian, and Variation of the Néedle, the thynges proposed to be shewed.

Example of twoo obseruations made at Limehouse the 29. of Julie 1581. in the forenoone.

The first eleuation 21. d. 0'. Variation 100. d. 30'. from North to Weste. The seconde eleuation 50. d. 0'. Variation 48. d. 0'. from North to Weste. Difference of the Azimuths 52. d. 30'. The declination 16. d. 14'. Northerly.

LEt I D B. be the Horizō of the Globe. C A B. the meridian circle. F G A. the Azimuth of the greater eleuation shewed by the quadrant of altitude vpon the Horizon at F. 10. d. from the meridian circle of the Globe C. F G. the



the greater eleuation marked vpon the Globe at G. FD. the difference of the Azimuths vpon the Horizon, 52.d.30'. E, the prick of the lesser eleuation marked vpon the Globe in the Azimuth A E D.

Then openyng your Cumpasses to 73.d.46'. of the Equinoctiall (which is the complement of the declination) and settyng one ende vpon G. the poinct of the greater eleuation, describe with the other ende, an ark or peece of a circle at H.

This done, set one foote of the Cumpas vnaltred in E. the lesser eleuation, and with the other ende describe a peece of a

circle crossyng the former ark at H. this intersection shall bee the eleuated Pole.

Then set the quadrant of altitude vnto the poinct H. and it will shewe the meridian to crosse the Horizon at K. So shall you haue the eleuation of the Pole K H. 51.d. ½. or there about. And the true meridian K A I. And from K. to D. the Horizontall distance 90.d. ¼. which subtracted from K I. 180.d. the semicircle of the Horizon, resteth the ark D I. 89.d. ¼. the distãce of the Azimuth of the first obseruation from the meridian I. which distance compared with the variation found vppon the Instrument at the first eleuation 100.d. 30'. and deducted frõ the same, resteth 11.d. ¼. Therefore I say, the true meridian shewyng the Pole Artik is 11.d. ¼. to the Westwards of the magneticall meridian shewed by the Needle, and consequently the variation of the Needle 11.d. ¼. from the North to the East.

In this example the declination is subtracted from the quadrant, because the Sunne is betweene the Equinoctiall and the eleuated Pole, but if the Equinoctiall were betweene the eleuated Pole, and the Sunne then should you adde the declination to the quadrant, and with that distance taken vpon the Equinoctial with your Cumpasses, proceede as in the former example

These examples that I haue shewed, and suche like experiments to be done vpon the Globe, are easie to be conceiued, and the reasons very manifest: but the truth of the matter consisteth in the exactnes of the Instruments, and the orderly application and handlyng of them.

I might here haue annexed the maner, how vpon two obseruations of the Sunnes eleuation in forenoone or afternoone and difference of the Azimuths, to calculate the premisses more exactly by the table of Sines and doctrine of sphericall triangles: but that it is a very tedious way, and my meanyng is rather to giue the Reader a proof of the pleasant vse of these calculations (whiche I thinke I haue sufficiently done in the former Chapters) then to cloy hym at the first with the hard

and

and painfull practise of many examples. Notwithstanding, for the satisfaction of some, I will breefly set downe the grounde and summe of the worke, which is this.

The complements of your two eleuations, are two sides of a sphericall triangle not rectangle. The angle by these two knowen sides contayned at the Zenith, is giuen by the difference of the Azimuths or variations vppon the Instrument. Wherefore by the 28. of the 4. of Regiomontanus the third side (whiche is the ark comprehended betweene the two eleuations) and the other angles may be giuen.

Then haue you an other like triangle, whose three sides are these: the first, one of the foresaied complements of eleuation: the seconde, the arke of the circle of declination, betweene the Sunne at the instant of the same eleuation, and the eleuated Pole. The third side is an arke of the meridian betweene the Zenith and the Pole: whiche is the complement of the eleuation of the Pole, or latitude of the place. The twoo first sides are alwaies giuen. For findyng the third side, it is necessarie to knowe the angle that the twoo giuen sides containe, whiche is the difference of twoo angles, whereof one is an angle of the first triangle giuen, the other an angle contained betweene the arke of the circle of declination, and the third side of the first triangle, whiche angle is diuersly founde, and beeyng founde and subtracted from the other angle, or that from it, the difference is the angle of this other triangle: And so haue you in the Sphericall triangle twoo sides, and the angle by the same twoo sides contained, giuen. And by the same 28. of the fowerth of Regiomontanus the thirde side is found, the complement whereof is the eleuation of the Pole.

And the eleuation of the Pole, and declination of the Sun beeyng giuen, the fowerth Chapter sheweth by one obseruation, to finde the Variation of the Needle.

Of the Variation

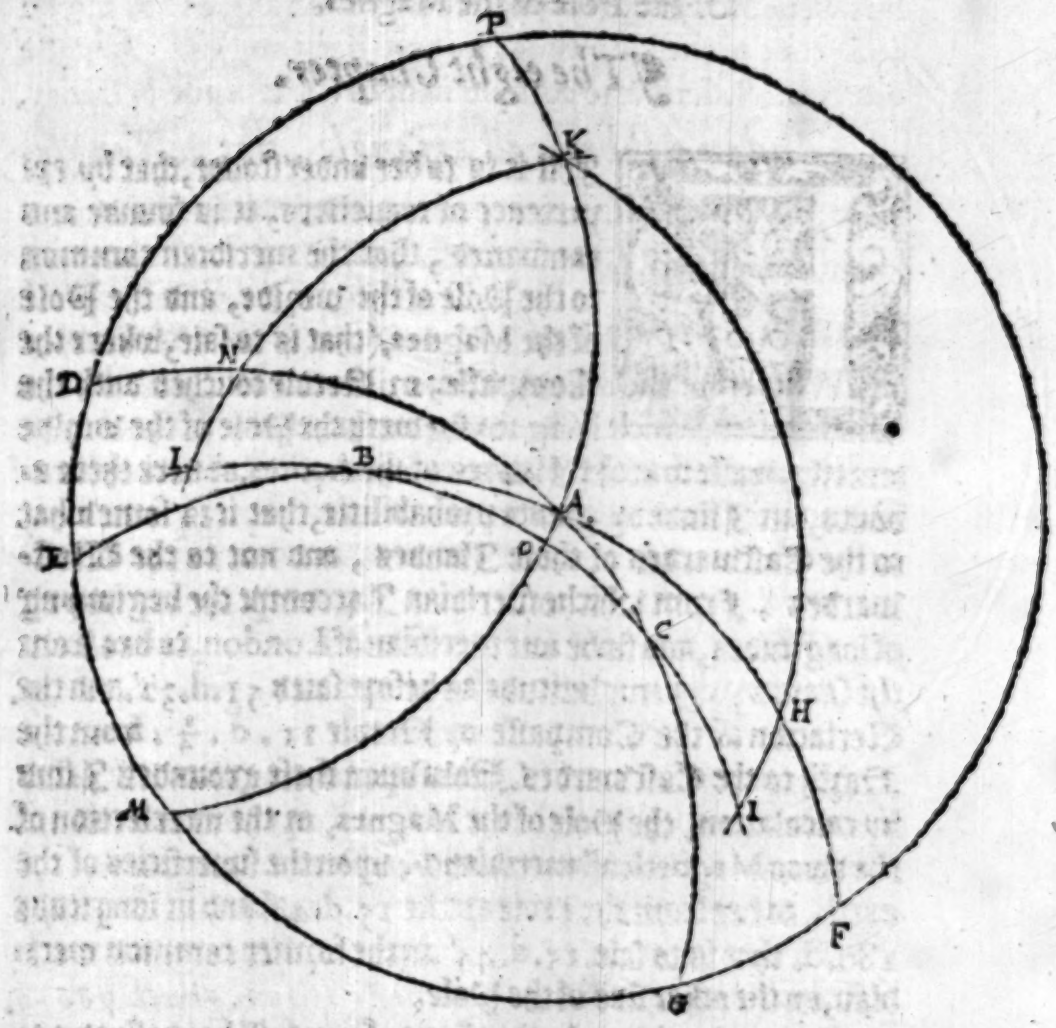
Of the Pole of the Magnes.

¶ The eight Chapter.

FIrst it is to bee vnderstoode, that by experience of trauellers, it is founde and confirmed, that the meridian common to the Pole of the worlde, and the Pole of the Magnes, (that is to saie, where the Compasse, or Needle touched with the Magnes, sheweth the Pole of the worlde directly,) passeth at the Ilandes of the Açores, or nere there aboute, but I finde by greate probabilitie, that it is somewhat to the Eastwardes of those Ilandes, and not to the Westwardes. From whiche meridian I accompt the beginnyng of longitudes, and finde our meridian of London, to bee from the same 23.d.½. our latitude as before saied 51.d.32′. and the Veriation of the Compasse or Needle 11.d.¼. from the Northe to the Eastwardes. Now vpon these groundes I finde by calculation, the Pole of the Magnes, or the intersection of the twoo Magneticall meridians, vpon the superficies of the earth, to bee from the Pole artike 25.d.44′. and in longitude 180.d. that is to saie. 25.d.44′. in the former common meridian, on the other side of the Pole.

It maie bee happely that some of you will bee desirous to knowe the maner how this Magneticall Pole is founde out, that you maie apply the same to like purpose hereafter. Therfore I thought good to sette doome an example of the former calculation.

LEt A. bee the Pole Artik. PEF. the Equinoctiall. DAG. the common meridian of the Pole Artik, and Pole of the Magnes. EAF. the meridian of *London*. LOI. the magneticall meridian for *London*. B. for the place of *London*. HI. the quantitie of the angle of Variation at the ende of the quadrants BH. and BI. C. the intersection



section of the two magneticall meridians. C L. and C N. two quadrants of the said magneticall circles, includyng the ark L N. the quantitie of the angle at C. P A M. the Semicircle of a meridian crossing the magneticall meridian of *Lõdon* in the poinct O. at right angles.

Make out the quadrants I H K. and L N K. so shall they crosse them selues with the quadrant O A K. at the poinct K.

Now haue you A B C. a sphericall triangle, two angles whereof and the common contaynyng side of them, are giuen. A B C. 11. d. $\frac{1}{4}$. the angle of Variation at *London*.

B A C.

B A C. 156. d. 30'. the complement of the angle D A E. (the difference of the longitudes) to two right angles. And the side A B. 38. d. 28'. the complement of the latitude of *Lõdon*.

And in a spherical triangle, not rectangle, whose two angles are giuen, and their common contaynyng side, the other angle and sides shalbe knowen, by the 31. of the 4. of Regiomontanus.

Wherefore the arke A C. the distance of the two Poles shalbe giuen, which is the thyng required.

For as the sine of B H. is to the sine of H I. so is the sine of B A. to the sine of A O. and three of them beyng giuen the 4. is found.

90 0'.	11. 15'.	38. 28'.	6. 58'.
B H.	H I.	B A.	A O.

If. 100000. giue. 19509. —— then. 62205. gineth. 12135.

Now as A K. is to A H. (the sines I meane) so is K O. to O I. but the three first are knowen A K. and A H. by their complements, and K O. the quadrant. Therefore the 4. is giuen.

83. 2'.	51. 32'.	90. 0'.	52. 4'.
K A.	A H.	K O.	O I.

If. 99261. giue. 78297. —— then. 100000. gineth. 78879.

And as B A. is to B O. (the complement of the arke O I. last founde:) so is A E. to E M. the quantitie of the angle B A O.

38. 28'.	37. 56'.	90. 0'.	81. 12.
A B.	B O.	A E.	E M.

If. 62205. giue. 61474. —— then. 100000. gineth. 98824.

So hauyng E M. 81. d. 12'. the quãtitie of the angle B A O. I subtract the same from E G. 156. d. 30'. the quantitie of the whole angle B A C. rest M G. 75. d. 18'. the quantitie of the angle C A O. to the which is equall the opposit angle P A D.

And

And as AP. is to PD. so is AK. to KN.

90.0°.	75.18'.	83.2'.	73.48'.
AP.	PD.	AK.	KN.

If. 100000. giue. 96726. —then. 99261. giueth. 96011.

The complement of whiche ark KN. is NL. 16.d.14. the quantitie of the angle ACB. And as NL. is to NC. so is AO. to AC. Wherefore I say.

16.14'.	90.0'.	6.58'.	25.44'.
NL.	NC.	AO.	AC.

If. 27954. giue. 100000. —then. 12135. giueth. 43410.

Which is the distance of the Pole of the Magnes from the Pole Artik: the thyng that was sought.

¶ Of the poinct Respective.

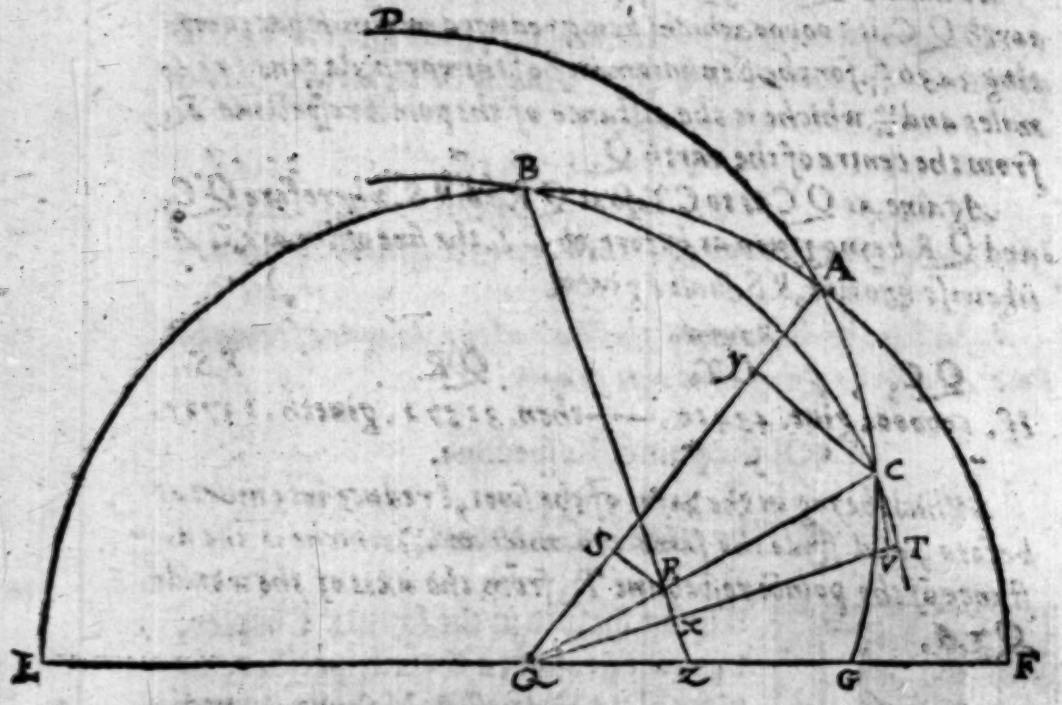
¶ The ninth Chapter.

HAuyng shewed in the former Chapter, vpon the grounds therein specified, the place of the Pole of the Magnes, vppon the superificies of the earth: there resteth now to bee declared, of the poincte Respective, where it should be, by the newe propertie founde of the declinyng of the Needle, at this place for London 71.d.50'.

First it is to bee considered, that as the Magneticall meridians doe crosse them selues at their Pole, before specified: so doe their plaines likewise crosse in a right line, passyng by the saied Pole, and the centre of the earth. Then producyng a straight line, in the Magneticall plaine of London, declinyng from the plaine of the Horizon 71.d.50'. where the same doth crosse with the former common section of the twoo plaines, there by reason should the poinct Respective bee. Whiche intersection I finde to bee from the centre of the earth 1085.

F.i. miles

miles (after the rate of 60. to a degree in the Equator, and $3436\frac{4}{11}$. for the Semidiameter of the earth) and the distance of the same from the axis of the world 471. miles.



LEt the circles be as in the last demonstration. And Q. the centre of the earthe. Then QA. the axis of the worlde. QC. the common section of the magneticall plaines. BZ. the line of the Needles declination crossyng the saied common section at R. whiche is the poinct respectiue. QT. a straight line crossing BZ. at right angles in X. QR. the distance of the poinct respectiue from the centre of the earth. RS. the distance thereof from the axis. Now as QV. is to QC. so is QX. to QR. But the three first are knowne. QV. the seconde right sine of the ark CT. 9. d. 4'. (the difference of the ark BT. 71. d. 50'. And BC. 62. d. 46'.) Then QC. the Semidiameter or whole sine, and QX. the second right sine of the ark BT. Wherfore QR. shalbe giuen, by the 4. of the sixt of *Euclide*.

30.56. 90.d. 18.16.

QV. QC. QX. QR.

If. 98750. giue. 100000. ——then. 31178. gineth. 31572.

So haue I QR. in suche parts as the Semidiameter of the earth QC. is 100000. which (beyng reduced into miles accompting 3436 $\frac{4}{11}$. for the Semidiameter of the earth) do giue 1084. miles and $\frac{10}{11}$. whiche is the distance of the poinct respective R. from the centre of the earth Q.

Againe, as QC. is to CY. so is QR. to RS. wherefore QC. and QR. beyng giuen as before, & CY. the sine of the ark CA. likewise knowne, RS. shalbe giuen.

25.44.

QC. CY. QR. RS.

If. 100000. giue. 43410. ——then. 31572. gineth. 13705.

Which beyng in the parts of the sines, I reduce into miles as before, and finde the same 470. miles and $\frac{10}{11}$. whiche is the distance of the poinct respective R. from the axis of the worlde QA.

¶ Of the inconueniences and defects in sayling, and in description of Countries, caused by the Variation of the Cumpas.

¶ The tenth Chapter.

IN all sea chartes generally, whiche are made without consideratiō of the variation, are committed great errours and confusion. For, either the partes in them contained, are framed to agree in their latitudes by the skale thereof, and so wrested from the true courses that one place beareth from an other by the Cumpas, or els in setting the parts to agree in their due courses, they haue placed them in false latitudes, or abridged, or ouerstretched the true distances betweene them.

In the Marine plattes made for Newfoundlande, the coaste sette downe from Silly to Cape Raso is due Weste, whiche is founde to bee so by our common sailyng Cumpasse, whose wiers are sette at ½. a poinct from North to East, notwithstandyng Silly beyng in latitude 50.d. little more, Cape Raso in Newfoundland is founde to bee but in 46.d. ½, which is 3.d. ½. lesse then the latitude of Silly.

To make a shewe of reformation of this error, (caused by the Variation and settyng of the wiers in the Cumpasse) or to giue a light of that differences in latitude, thei haue placed in the plat against that coaste, a newe skale of latitude, some vpon the line of South and North, and some other haue placed the same vpon the line of North Northeast, & South Southwest, (because that poincte of the Cumpasse sheweth the Pole nerest in that place) and haue furnished the degrees thereof, agreeably to the latitude of Cape Raso: and by that meanes haue had a double skale of latitude, one for the Easter costes, the other for that Weste. But how farre the same hath been from reformyng the error, or giuyng any helpe to Nauigation, you maie easely iudge.

Others to auoide that error of the difference in latitude in that voyage and course, haue vsed Cumpasses whose wiers haue been sette directly vnder the North poincte, and thereby sailyng Weste from Silly, haue fallen to the Northwardes of Cape Raso about 50. leagues, and in latitude nere 49.d.

Some other haue vsed in the same voiage to place a blank Flye vpon their sailyng Cumpasse, whiche thei haue remooued from tyme to tyme, as thei haue iudged the variation hath altered, by whiche waie, albeeit thei maie seeme to keepe them selues neerer the parallell, yet the same in Nauigation worketh the greatest confusion of all other, and therefore is to bee vtterly abolished.

In our voiages from hence Eastwardes to S. Nicolas in Russia, and to the Narue in Liuonia &c. the Marine plattes of the coastes are described by our common sailyng Cumpas, with consideration of the variations at diuers places, where-

by

by the true meridians reformedly set doune, declining from ꝑ parallell meridians of the plat, doe necessarily widen Northwardes, and straighten to the Southwardes, contrary to the true forme and nature of meridians. And yet notwithstanding, that is the best meanes hetherto knowen, to reforme in plat, the errors that els would growe, by the strange variations that waie.

And albeeit these plattes serue verie well for those Nauigations, yet by meanes of the variations considered, the forme of those coastes is so distorted from the right shape it should beare, beyng truely described vpon the Globe or otherwise in plaine, accordyng to the true latitude and longitude: That whereas the Narue (beyng in latitud. 59. d. ¼. and in longitude from the meridian of London 26. d. 10'.) should be from S. Nicolas 9. d. 40'. in longitude to the Westwardes (S. Nicolas beyng in latitude 64. d. 35'. and in longitude from London 35. d. 50'.) In the sailyng plat it is brought to bee in the meridian of Colmogorod, (whiche is in latitude 64. d. 20'. and in longitude from London 37. d. 45'.) whiche is 1. d. 55'. to the Eastwardes of the meridian of S. Nicolas.

In the Mediterranean Sea, and in the coastes thereof, where, in great reason should be the perfectest descriptions of the worlde, for that in those parts haue been the seates & abodes of the moste famous and learned men in all ages, we see notwithstandyng in the Marine plattes of those partes, grosse errors committed, through want of knowledge of the variation and the vse thereof, in whiche thei haue not accompted of 3. 4. or 5. degrees error in the latitude of places.

But those defectes of the latitudes, haue been verie well reformed, by the famous and learned Gerardus Mercator (whom I honour and esteeme as the cheef Cosmographer of the worlde) in his vniuersal Mapp, which though he haue made with sailyng lines, and dedicated to the vse of Seamen, yet for want of consideration of the Variation, and partly by augmētyng his degrees of latitude towardes the Poles, the same is more fitte for suche to beholde, as studie in Cosmographie, by

readyng aucthours vpon the lande, then to bee vsed in Nauigation at the sea.

There is also in the same Vniuersall Mappe, and likewise in all other moderne Mappes of the North partes of Europe, a greate fault, by placyng twoo Wardhouses distant one from the other aboue 20. d. in longitude, whereas in deede thei are but one thyng, and no suche distance betweene them. This error hath growen by taking Wardhouse, and the Sea coastes, from thence to S. Nicolas, Vaigats and the Ob &c. out of the Mappe of Anthony Ienkinsons trauaile to Boghar and Persia. In the whiche I placed that border of the Sea coaste, and for some causes went no further in that descriptiō then Wardhouse, whiche is in latitude 70. d. ½. and in longitude from London 29. d. Wherfore to accomplishe the whole border of that coaste, he was forced to seeke some other description to ioine with it, & tooke as appeareth the Mappe of Olaus Magnus of the North countries, wherin he found likewise Wardhouse, but falsly placed, in latitude about 19. d. too muche, and in longitude as muche too little, the which, although he might take to bee the same specified in Maister Ienkinsons Mappe, yet he was constrained to separate thē the saied distance of 20. d. in lōgitude (or to leaue there so much superfluous roome) otherwise he should haue thrust the South partes of those cōtries togethers, and confounded the whole description.

And albeeit he had had the entire sailyng plat, that wee vse for those partes, yet if he had not knowen the secret effect of the Variation in the makyng thereof, he might haue fallen into the like absurditie or worse. But of those coastes and of the inwarde partes of the countries Russia, Muscouia &c. I haue made a perfect plat and description, by myne owne experience in sundrie voiages and trauailes, bothe by Sea and Lande to and fro in those partes, whiche I gaue to her Maiestie, in Anno 1578.

Besides these and like imperfections proceadyng of the Variation, there is yet an other inconuenience, whiche oftentymes encreaseth the former errours, and that is, the diuers

placyng

placyng of the wiers fixed to the Flie of the Cumpasse.

This varietie of settyng the wiers, hath caused greate cõfusion in Nauigation, and in other accomptes of Sea causes, for when it is saied, that from suche a headlande, to suche a place is suche a course, or at suche a place the Moone vppon suche a poincte of the Compasse maketh the full Sea, it is requisite to bee demaunded, by what Cumpasse the obseruation was made, whereas if the wiers had not been altered from the North poinct of the Flie, (whiche I wishe had neuer bin any where) these doubtes had been auoided.

It behoueth therefore all men that will make Hydrographicall discriptions for the vse of saylyng, to haue speciall regarde of the Cumpas by which their obseruations are made, and if they collect notes made by sundry Cumpasses of diuers setts, they ought to reduce all the varieties vnto some one certaine, and to giue notice of the same, in their platt: And not to make a confused mingle mangle by ioyning together all varieties of obseruations, notes and reportes, as the Portingales and Spaniards haue done, in compoundyng these North parts of the worlde, with their owne discoueries, without consideration of the diuers sorts of the seuerall cumpasses by which thei were made.

Also it importeth all Maisters, Pilots and others by what name so euer that shall giue directions in Nauigatiõ, to looke circumspectly to the settyng of the wiers of the Cumpas by whiche they shall sayle, that the same Cumpas be correspondent, to the lines of the Sea Card that they shall vse: that is to say, that it be of the same set for the Variation, that the Cumpas was of, by which the Carde was made.

And seyng wee haue in this our Countrey acquainted our selues commonly in our obseruations and Nauigations, with the Cumpas, whose wiers are set at $\frac{1}{2}$. a poinct from North to East, I meane in the discriptions that I shall make, to apply the same agreable to the said Cumpas, and would vse the like without alteration (and also the straight lines in Sea Cardes) if I should sayle rounde about the world to make the

description

description thereof, but alwaies with regarde of the seuerall variations of euery place where the same should be obserued.

¶ Of the Instruments and rules of Nauigation.

¶ The eleuenth Chapter.

AMongst the rules and Instruments for Nauigation, all suche are vaine and to small purpose, wherein the true meridian is presupposed to be giuen by the magneticall Needle, without due consideration of the variation for that they are all grounded vppon false suppositions. Hereby it commeth to passe that one Michiel Coigner of Antwerp in his New instruction (as he termeth it) of the most excellent and necessary poincts of Nauigation, wherein he sheweth the making and vse of a Nauticall Hemisphere, which he preferreth before all other Sea Instruments, is very childishly abused. For where as he pretendeth by it, to giue the elenation of the Pole and the houre and instant of the tyme of the day, by any one obseruation in any place, besides that it is of all other that hitherto haue been vsed at Sea, the most tedious and vnfit for that purpose, it is also by reason of the variation not considered, mere false and erronious. For, the true meridian which is the grounde of his purpose, is as farre to seeke as the thyng he promiseth to giue by the same. The like may be said of al other Instruments made vpon the same ground whether they serue for the Sea or Land.

The same Author in the 4. Chapter of his booke, entreting al saylyng vpon the poincts of the Cumpas, saieth, that in sailing South or North, he shall passe by the Poles of the worlde, and keepe vnder one meridian, till he came to the place from whence he first departed. And vppon the poincts of East and West out of the Equinoctiall, he shall saile vnder a parallell, till he returne to the place from whence he went. But in say-

lyng

lyng vppon the poinct of Northeast, he shall describe a spirall line inclyning by little and little towardes the Pole, as in his demonstration thereof in the same Chapter appeareth. But for want of due consideration of the variation, his rules, reasons and demonstrations, and suche others hitherto giuen for like purposes, are friuolous and false.

For if he direct his saylyng by the Cumpas (as of necessitie he must, beyng the onely Instrument for that purpose) it is manifest, that whether he sayle North or South, East or West, or by what other poinct so euer, the Cumpas not respectyng alwaies the Pole of the world, as he supposeth, but some other poinct or poincts distant from the same, shall leade hym accordyngly, whereby he shall neither keepe vnder one meridian, nor vnder one parallell of latitude, neither make such a spirall line to the Pole of the world, as he demõstrateth. His fault in settyng downe those rules is so muche the greater, in that he acknowledgeth in the Chapter next before the variation at Antwerp, to bee about 9.d. from North to East accordyng to Mercators position, of the Magneticall Pole, which he also confirmeth by his owne experience.

But it seemeth he hath followed, that excellent Mathematician Petrus Nonius, especially concernyng the saylyng vppon the poincts of East and West. For he, in his first booke of the rules and Instruments of Nauigation, enforceth hym selfe to proue and demonstrate, that in saylyng East or West, out of the Equinoctiall, the course is performed by peeces of great circles, and yet describeth a parallell. But how that may stande with the principles of Geometry, I referre the iudgement to the expert Mathematicians, for it is like as a circle should be made of straight lines, which is impossible.

It appeareth in the discourse that he hath made of those matters, that he had not a right iudgement of the nature of the Cumpas in saylyng (admitting the same to shew the Pole without Variation) for if he had, he would neuer haue entred into suche a Labyrinth as he did. But he thought it a great absurditie that the Cumpas in euery Horizon should shewe the

meridian and Poles of the world by the poincts of South and North, and by the poincts of East and West to shewe in the Horizon the verticall and Equinoctiall East and West (being a great circle) and yet in saylyng East or West, except in the Equinoctiall, it should performe but a parallell.

But it is to be vnderstood, that albeit the poincts, or lynes of the Cumpas doe alwaies in euery Horizon represent great circles in the Heauens, the points of South and North the meridian, and the poincts of East and West the verticall circle of East and West, eche crossyng other at right angles, and likewise of the other poincts. (The reason whereof is, because the Cumpas lieth euery where leuell with the Horizon, so as a perpendicular line descendyng from the centre thereof at right angles with the plaine of the same, will alwaies fall vpon the centre of the earth, and consequently be the Semidiameter of a great circle.) So that where so euer the Cumpas be caried, these circles are supposed to be caried about with it, and the view of euery thyng in the Horizon represented by the poincts thereof, is likewise in great circles: Yet in saylyng by the Cumpas, the poincts of South and North onely, describe great circles generally, which are the meridians, & the points of East and West, describe a great circle in the Equinoctiall onely: in all other places out of the Equinoctiall, they describe but parallells. And the saylyng vppon any other poinct of the Cumpas, from any place, describeth a spirall line, according to the angle it maketh with the meridian. And hereby in saylyng vpō the poincts of East or West, out of the Equinoctiall, (the North poinct alwaies respectyng the Pole) the course performeth a parallell, accordyng to the distance of the centre of the Cumpas from the Pole. The maner thereof you may perceiue by fastnyng a small threed or Virginall wier at the Pole of a Globe, or centre of a circle, which shall represent a moueable meridian to bee caried about the Globe or circle, and fixe vppon the same, a small Flye of a Cumpas, so as the line of South and North be answerable to the threed or wier, and the North poinct thereby alwaies respect the North Pole: then

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in turnyng the threed about the Globe or circle, vpon the Pole or center, if the center of the Flye bee out of the Equinoctiall (between it and the Pole) albeit the points of East and West crossyng the same line and moueable meridian at right angles, doe shewe the verticall East and West vpon the Globe, which is a great circle, yet in caryng the same Flye vpon the threed or moueable meridian, about the Pole or center, you shall by the center of the same Flye, describe but a parallell, accordyng to the distance there of from the Pole of the Globe, or center of ỳ circle, not vnlike the circular motiõ of a Horse drawyng in a mill, who though he looke forth straight in a right line, yet beyng fastned to the beame of the mill, is forced to make his course in a circle, whose Semidiameter is the lẽgth of the beame contayned betweene the Horse, and the centre of the mill, or milpost.

And as in the Equinoctiall, the line of South and North in the Cumpas (by supposition representing the meridian) is parallell to the Axis of the earth (which is the common section of all the meridian plaines) and the line of East and West crossyng the same Axis at right angles, representeth the verticall East and West, which is the Equinoctiall, imaginyng to descende from the centre of the Cumpas a line, to fall perpendicularly, and at right angles with the Axis of the worlde (whiche shall bee at the centre of the earth) and in saylyng East or West by the Cumpas, the imagined perpendicular line being caried about with the same (makyng alwaies right angles with the Axis) shal describe the plaine of the Equinoctiall equidistant from the Poles of the world, and at right angles with the Axis, and the poinct of the same line at the centre of the Cumpas, the circumference of the Equinoctiall, vppon the superficies of the Sea: So beyng from the Equinoctiall on either side, imaginyng the line of South, & North in your Cumpas to represent alwaies the Axis of the world, and to lye parallell with it, the line of East and West must crosse the same Axis alwaies, at right angles: and supposing a line to fall from the centre of your Cumpas to the Axis of

the worlde, makyng right angles with the same Axis. In sayling East or West, that imagined line beeyng caried about with the Cumpas (alwaies at right angles with the Axis) shall describe the plaine of a parallell, equidistant to the plaine of the Equinoctiall, and the poinct thereof at the centre of the Cumpas, the circumference of the parallell vppon the superficies of the Sea: which parallell should be represented by the poincts of East and West of the Cumpas, if the line of South and North of the same were parallell to the Axis of the earth, as was supposed: but it is not. And therfore as they decline one from the other, so doeth the verticall circle of East and West shewed by the Cumpas, decline from the parallel circle euery where.

The angle of whiche declination, is alwaies equall to the latitude of the place, or distance of the parallell from the Equinoctiall.

But as I haue already sufficiently declared, the Cumpas sheweth not alwaies the Pole of the worlde, but varieth from the same diuersly, and in sayling describeth circles accordyngly. Whiche thyng if Petrus Nonius and the rest that haue written of Nauigation, had ioyntly considered in the tractation of their rules and Instruments, then might they haue been more auaileable to the vse of Nauigation, but they perceiuyng the difficultie of the thyng, and that if they had dealt therewith, it would haue vtterly ouerwhelmed their former plausible conceits, with Pedro de Medina (who as it appeareth hauyng some small suspition of the matter, reasoneth very clerkly, that it is not necessary that such an absurdity as the Variation, should be admitted in such an excellent art as Nauigation is) they haue all thought best to passe it ouer with silence. But I hope suche as intende hereafter to write of Nauigation, will either frame their rules, precepts, and Instruments, with regarde of the Variation, as herein I haue shewed, or els ease them selues of that trauaile, for as good none as vnprofitable.

Of

¶ Of the application of the Variation to the vse of Navigation.

¶ The twelfth Chapter.

VPon the Hypothesis of the Pole of the Magnes on the superficies of the earth, and the poinct Respective in the body thereof, accordyng to the former calculatiõs, might be inferred many pleasant conclusions, both for the longitude and latitude of places.

But touchyng the poinct Respective by the declinyng of the Needle, seeyng this is the first and onely experiment that hath been made of it, I can not inferr any further matter thereof, then that whiche I haue already set downe, vntill by obseruations in other places, we finde how it will holde.

And as for the Variation, if it were generally regular and certaine, as in some part it seemeth to be: (that is to say, from hence Westwardes to Meta Incognita, Newfoundland, Florida, and that part of the coast of America) then might there be giuen by it generall rules most certaine and commodious for the vse of Nauigation.

And by the same Hypothesis of the Pole of the Magnes at 25.44'. from the Pole of the world, the greatest variation of the Needle in the Equinoctiall, should be (at 90.d. of Longitude) 25.44'. from North to East. And consequently the greatest variation in the parallell of 70.d. should bee (at the longitude of 128.d.51'.) from North to East 81.d.14. And in the meridian of 180.d. of longitude between the two Poles, (the Pole Artik I meane, and the supposed Pole of the Magnes,) there should the North poinct of the Needle or Cumpas respecting his own Pole, shew the South, and the South point, the North Pole of the world.

But in my trauelles to the Northest parts, I haue found this position of the magneticall Pole clene reuersed: for where

as the angle of Uariation from hence Eastwardes in the parallell of 70.d. should encrease and growe wider, till it came to 81.d.14'. from North to East as before. At the Iland Vaigats beyng in longitude from London 58.d. and in the same parallell of 70.d. where, by the Hypothesis, the variation should be 49.d.22'. from North to East, I finde the Needle to vary 7.d. from North to West. And the like effect I haue found by diuers obseruations in sundry other places of the East partes. Whiche obseruations with many more that I haue caused to bee made, and daply procure to be done in diuers other Countries, I reserue, with intent (if it bee possible) to finde some Hypothesis for the saluyng of this apparant confused irregularitie.

At Ratisbona or Regensburg in Bauaria, beyng in latitude 48.d.52'. and in longitude 36.d.20'. where, by the former position of the magneticall Pole at 25.d.44'. the Uariation should be 16.d.44'. from North to East. Gerardus Mercator found the same to be onely 11.¼. as I gather by his placyng of the magneticall Pole at 16.d.22'. from the Pole Artik vpon his obseruation made at that place: whiche confirmeth the retrograde qualitie in the Uariation from hence Eastwardes, as afore said.

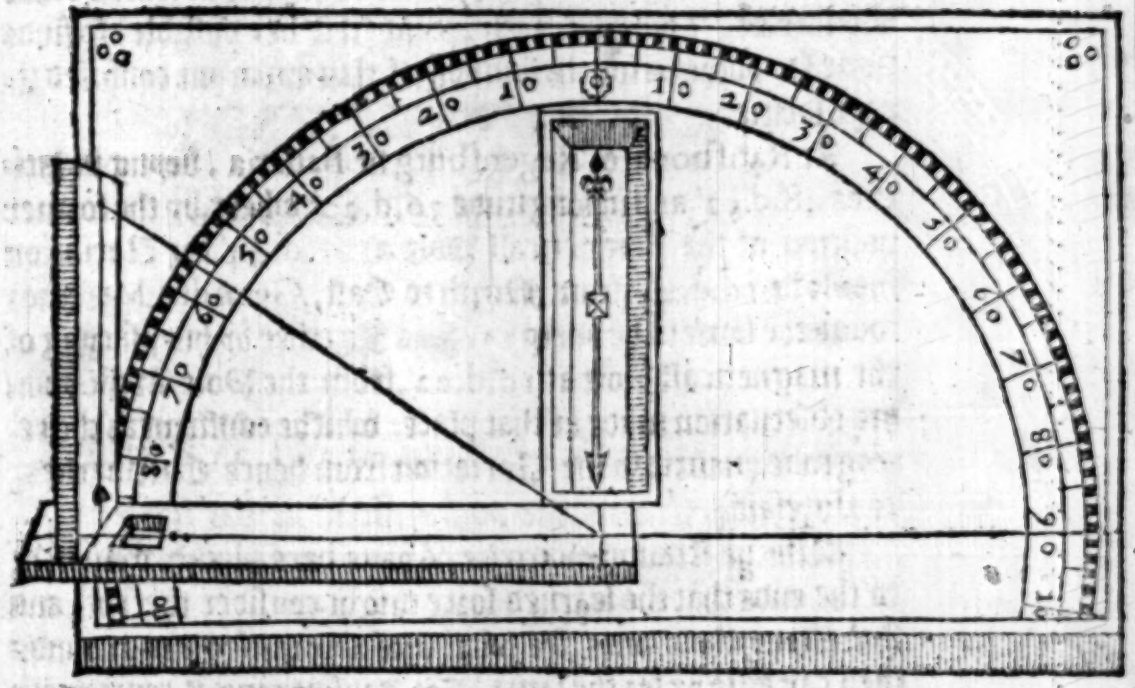
Whiche straunge varietie, I haue here plainly proposed, to the ende that the learned sorte might consider thereof, and sharpnyng their wits, see what probable causes and grounds they can assigne for the same. For, considerynge it remaineth alwaies constant without alteration in euery seuerall place, there is hope it may be reduced into method and rule.

As for that Westwardes, because it carieth proportion, and hath some apparant regularitie, I will apply the same to the generall commoditie of all suche as shall trauaile that waies: which if I should here particularly decipher, it would require a volume, whereby (contrary to my first intent) I should farre exceede the bounds of an addition, I will therefore abridge it to a Hydrographicall Plat, wherein all such errors and defects as haue been hitherto vsed, shalbe reformed,

whiche

which shall be easy for the meanest capacities to conceiue, and serue more effectually in vse, then if I should haue expressed the same by multitudes of rules in writyng. Therefore for this matter I referre you to the same, the whiche you shall looke for very shortly.

A new Instrument for the Variation.



BEcause I haue found some imperfections in the first Instrument for the Variation (whiche notwithstandyng doeth farre excell the Cumpasses of Variation heretofore vsed for that purpose) I haue here set downe the forme of a newe Instrument, wherein all scrupie of doubtes and defects that might growe by the other is quite auoyded. Whiche beyng once exactly placed with the Needle vpon the line of South and North, will serue without remouyng for a whole daies obseruation, the Index onely beyng caried about with

Of the Variation

with the Sunne, to giue the degrees of Azimuth vppon the Instrument by the shadowe of the line thereof, and is otherwise to be vsed accordyng to the prescript rules of the former Instrument.

These Instruments are made by Robert Norman, and may be had at his house in Ratclif.

Imprinted at London for Richard Ballard, and are to be solde at his shop at Sainct Magnus corner in Themes streate, Anno. 1581.